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TP 6067E

RADAR DIGITIZATION, CONVERSION AND ANALYSIS OF AN ICE HAZARD DETECTION/ COLLISION AVOIDANCE SYSTEM

Prepared for: The Transportation Development Centre
Transport Canada

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resource systems inc

TP 6067E

RADAR DIGITIZATION, CONVERSION AND ANALYSIS OF AN ICE HAZARD DETECTION/ COLLISION AVOIDANCE SYSTEM

By

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Viatec Resource Systems Inc.
Calgary, Alberta

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PREPARED FOR THE

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TRANSPORT CANADA

"The contents of this report reflect the views of the contractor and not necessarily the official view or policies of the Transportation Development Centre of Transport Canada."

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17. Abstract

Analysis of a radar data set collected in Arctic waters in 1981 has revealed that a number of digital radar processing techniques can be utilized to improve the detectability of icebergs. These include scan to scan averaging, dynamic threshold processing and statistical decision making, a basic form of artificial intelligence applied in an iceberg detection situation. Scan to scan averaging should utilize at least 4 and up to 32 scans. The use of theoretical decision discriminant functions has been established to measure skill in target detection. The data analysis suggests that the same sort of conclusions based on theoretical analysis operate in practice. Therefore, analysis of the type presented can dramatically improve image intelligibility and target detection capability. Real time A/D conversion, scan conversion and processing for complete 360°sector at 20 MHz sampling rates with 8 bit resolution needs to be conducted if Ice Hazard Detection/Collision Avoidance Systems (IHD/CAS) are to become successful. The IHD/CAS system specification has been updated to incorporate these requirements.

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17. Résumé

L'analyse d'un ensemble de données radar recueillies dans les eaux arctiques en 1981 a révélé qu'un certain nombre de techniques de traitement de données numériques peuvent servir à améliorer la détectabilité des icebergs. Ces techniques comprennent la moyenne d'un balayage à l'autre, le traitement de valeurs seuils dynamiques et la prise de décisions à partir de données statistiques, cette dernière technique étant une forme élémentaire d'intelligence artificielle appliquée à la détection d'icebergs. La moyenne d'un balayage à l'autre devrait comprendre de 4 à 32 balayages. Les fonctions de résolution pour prise de décisions théoriques ont été établies pour mesurer la capacité de détection des cibles. L'analyse des données laisse croire que le même genre de conclusions basées sur l'analyse théorique existe dans la pratique. Par conséquent, l'analyse du type présenté ici peut améliorer considérablement l'intelligibilité de l'image et la capacité de détection. Il faut effectuer la conversion A/N en temps réel, la conversion de balayage et le traitement requis pour couvrir un secteur de 360°à une fréquence d'échantillonnage de 20 MHz et une résolution de 8 bits pour que les systèmes de détection et d'évitement des glaces flottantes deviennent efficaces. Les spécifications relatives à ces systèmes ont été mises à jour en vue d'inclure les nouvelles exigences.

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1. INTRODUCTION

In an attempt to improve the capability of radars to detect ice and icebergs as part of an improved Ice Hazard Detection/Collision Avoidance System (IHD/CAS), a number of approaches have been investigated by a multitude of researchers. These approaches can be categorized in three areas. The first relates to the improvement of the radar itself and its method of deployment, the second area concentrates upon display improvement and the third area has concentrated upon the development of entirely new radars such as HF radars and coherent radar systems.

This report will deal primarily with the second area, that of enhancing the display capability, although work in the other two areas will be reviewed. The specific objective of the project is to undertake a detailed analysis of radar data currently available, to identify data enhancing techniques and to refine accordingly the system specification for an Ice Hazard Detection/Collision Avoidance System.

The system specification itself has been "finalized" based upon the inputs from the work conducted as part of this contract, and inputs from other groups involved with the detection of ice and icebergs. Based on current technology, and the results of our work, it is safe to say that the specification is up to date and incorporates the best features of a number of potential sensors. However, as work continues in this area, it is expected that further evolution of the system will occur as sensors and data processing capabilities are improved. At a certain point in time, this development will need to be frozen, and a prototype system will need to be developed.

The emphasis on this second area of investigation concerned with display capability does not imply that this is the preferred method of improving the state-of-the-art in iceberg detection, but rather that under the limitations of the present data sets available, which have been recorded with current marine radars, obviously only processing techniques that can be implemented after the radar data has been recorded can be utilized.

This report consists of four parts. The first part deals with the signal processing techniques that were implemented. This includes the software necessary to conduct non real time threshold processing. The second section of the report details the system specification modified from previously produced specifications to incorporate the requirements of offshore operators. Appendix B of the report also includes drawings of the interface necessary to enable the IHD/CAS display to properly interface with conventional marine radars. The third part of the report reviews some of the other sensor development programs conducted by other groups, for example, that done at the Communications Research Laboratory of McMaster University. This section also includes time scales for development programs for East Coast Offshore and Arctic operations. The last section details recommendations for future work, including processing options that are worthy of more investigation.

2. SIGNAL PROCESSING OF RADAR SIGNALS

2.1 Objectives

By utilizing radar display signal processing techniques, an attempt has been made to demonstrate real improvement in the ability of ice hazard detection systems to discriminate between ice and iceberg targets and clutter or noise. The emphasis on signal processing undertaken under the terms of the contract has centered on data that has already been recorded on an analog recording system using operational marine radar. Therefore, the results of the work will lead to recommendations for signal enhancement techniques that are applicable to existing marine radars. These techniques may or may not be applicable to radars under development, for example, coherent radars of the type envisioned by McMaster University, but hopefully the advantage of conducting display processing with improved radars would be cumulative.

A number of techniques have been evaluated. A common factor involved in all of these techniques was that the processing was accomplished digitally. This approach is not state-of-the-art, but its application in the iceberg detection scenario is sufficiently recent that research groups are still debating the relative merits of different digital processing methodologies. However, the results obtained during the course of this work have enabled clarification of effective techniques. The steps required to properly digitize marine radar video can be specified much more clearly, and will be described in more detail in section 3.

In our case, the analog radar video and bearing information was digitized using the McGill Weather Radar Observatory digitizer. The digitizer accepted radar trigger, log video and binary azimuth information. The peak value of the log video for each range cell was converted to digital code having an intensity resolution of 64 levels (6 bits). The analog to digital converter was a high speed LSI chip capable of a 30 MHz sampling rate but operated at 5.5 MHz. Following A/D conversion, the digital signal was fed to a PDP 11/23+ computer. Here, the scan conversion software assigned a rectangular coordinate to digitized range and azimuth information. This information was passed via a Q-bus interface to a QRGB-256 plug-in single Board Color Imaging System, and subsequently displayed on a high resolution monitor. Figure 2.1 depicts the system configuration used for the analysis. All signal processing was accomplished using software. This resulted in non-real time performance, however, real time performance was not necessary in this case where techniques are simply being trialed, and not utilized in an operational sense.

The following techniques were utilized on a number of targets.

a) Scan to scan processing
b) Dynamic threshold processing
c) Combined averaging and statistical decision making

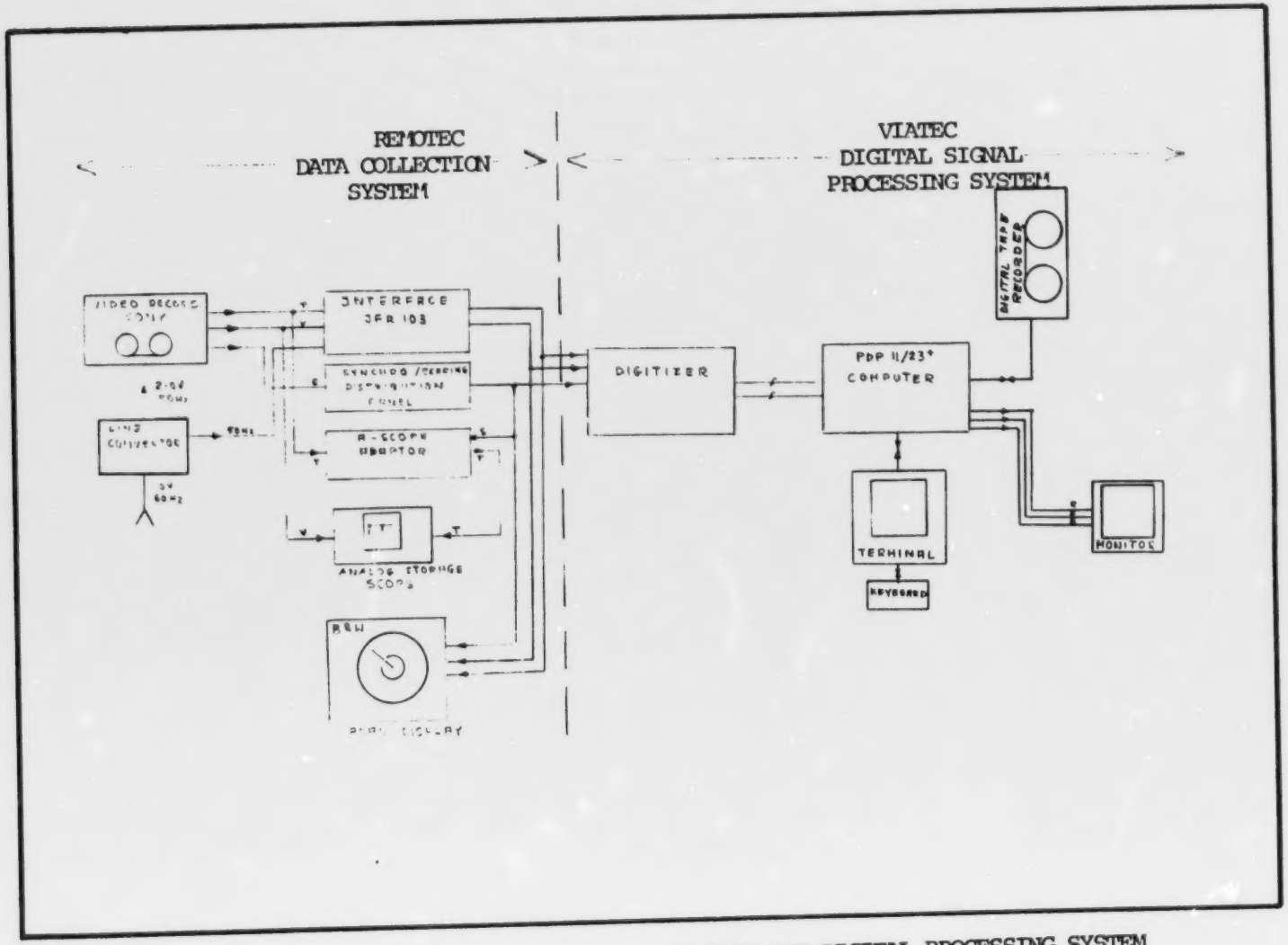


FIGURE 2.1 - DATA COLLECTION AND DIGITAL PROCESSING SYSTEM

The results are presented in a format that requires explanation. Because the system used for the processing did not work in real time, it was necessary to process sectors of data rather than full PPI scans in order to complete the work in a timely fashion. Although the computing time required to process the data was not that lengthy, the physical aspects of digitizing, scan converting, display and re-recording limited the amount of data that could be processed in the time available. In addition, the effects of processing needed only to be demonstrated in the vicinity of selected targets, obviating the need to process entire PPI scans, however an operational system will by necessity be required to perform image enhancement in real time or near real time.

The methodology utilized will be described later.

2.2 Theory

The detectability of icebergs in open water with radar is dependent on the ratio of the received signal from the iceberg to that of competing background signals. Typically the competing signals are receiver noise and sea clutter. The signal to noise ratio may be increased by increasing the trasmitter power, antenna gain or receiver sensitivity, however, these parameters will not increase detectability when sea clutter is the compteting signal.

The received signal from the ocean surface is dependent on the backscatter coefficient of the sea, σ_s°, and the are illuminated by the radar (ie. radar resolution cell).

The signal to clutter ratio for an iceberg which is small compared to the radar resolution cell is given as:

$$\frac{S}{C} = \frac{F_t^4 \sigma_t}{F_s^4 \sigma_s^\circ A} \qquad (1)$$

where F_t^4 = propagation factor for the iceberg

F_s^4 = propagation factor the sea

σ_t = iceberg radar cross section, m^2

σ_s° = backscatter coefficient of the ocean, m^2/m^2

A = area illuminated by the radar

$= \frac{C \tau R \theta}{2}$, m^2

where C = speed of light

τ = radar pulse length, seconds

R = range, meters

θ = radar horizontal beamwidth, radians

From equation (1) it is clear that the only radar parameters that will increase the signal to clutter ratio are the pulse length and horizontal beamwidth. At microwave frequencies very narrow beamwidths are achievable and short pulse lengths may be formed using pulse compression techniques, however, Williams, 1975, has suggested that decreasing resolution cell size does not necessarily mean increased performance as there will be a change in the observed statistics of the ocean sea surface.

The detection of signals in the presence of noise and clutter may be improved by forming the average of independent samples of the signal plus noise and clutter. Marine radar provides repetitive samples of this quantity, however, while the noise will be decorrelated (or independent) from pulse to pulse (about 1 msec) the clutter will be correlated. Typical decorrelation time for sea clutter will be on the order of 10 msec. To obtain independent samples of sea clutter, it is necessary to wait for a longer period of time before sampling or looking at the clutter. With standard marine radar this necessitates performing the averaging or processing on a scan (one antenna revolution) to scan basis thus insuring independent samples. Utilizing an incoherent radar (ie. the phase relationship between the transmitted signal and the received signal is unknown) an improvement of at least $\sqrt{n}$ in signal to clutter ratio can be obtained where n is the number of scans averaged.

For this reason, it could be expected that signal to clutter ratios could be improved with various averaging techniques. Utilizing analog data collected by Remotec Applications Inc. for Petro-Canada Exploration Inc. in 1980, a review was conducted in 1983 by Viatec Resource Systems Inc. and 18 potentially useful tapes were identified. Although absolute power measurements were not included in the data, and therefore precluded the possibility of measuring absolute improvements in signal to clutter ratios, it has been possible to demonstrate relative improvements in signal returns with the data. This relative improvement could then be compared with data collected and processed by Viatec for the Environmental Studies Revolving Fund to confirm our results.

2.3 Methodology and Results

2.3.1 Methodology Scan to Scan Processing

A number of scan to scan averaging have been proposed. In fact, integration of returns on a conventional phosphor type radar display occurs normally as a product of slowly decaying phosphor emissions at target locations. On a digital display this does not naturally occur, and this must be implemented in software or hardware if the technique is to be utilized. The result is that averaging occurs at each cartesian pixel over several successive images. Generally, for a series of N samples of signal plus clutter and noise, where the signal is correlated but the clutter is uncorrelated, integrating the samples will theoretically increase the signal to clutter plus noise ratio by a factor of root N.[1]

Several different techniques have been proposed. An equation which could be used is described.

$$S_{n+1} = S_n + \frac{1}{2^k} (X_{n+1} - S_n)$$

where S_{n+1} = is the new sample to be stored in video memory
S_n = is the old sample from memory
X_{n+1} = is the new input sample from the sensor
K = is a filter time constant

Another technique that could be implemented is decribed as follows:

$$S_{n+1} = \frac{(S_1) + (S_2) + (S_n) + (X_{n+1})}{n+1}$$

where S_{n+1} = is the new sample to be stored in video memory
$S...S_n$ = are the old samples from memory
$n+1$ = is the new number of samples being averaged
X_{n+1} = is the new input sample from the sensor

The scan to scan averaging techniques utilized at McGill University is as follows:

$$S_{n+1} = \frac{(S_n) + (X_{n+1})}{2}$$

S_{n+1} = is the new sample to be stored in video memory
S_n = is the old sample from memory

This improvement is true scan to scan average as significantly less than $\sqrt{n}$.

1 M.I. Skolnik Introduction to Radar Systems. McGraw Hill book Company, New York, 1980.

2.3.2 Results Scan to Scan Processing

The following set of illustrations demonstrates some of the results of scan to scan averaging techniques implemented by Viatec on two data sets, the first involving an iceberg data acquisition program aboard the SEDCO 706 and the second using data collected by Remotec Applications for Petro-Canada and the Transportation Development Center. Both data sets have been processed similarily and we are looking at four different events. Each has been displayed as it was collected, utilizing a program called VERIFY. Once the data has been looked at with areas of interest being selected the second program called M SCAN is run. This program reformats the data so that processing operations may be conducted. When it is run, a sector is displayed which appears similar in shape to a piece of pie, basically eliminating all the data which is not of interest. J SCAN is another program which does the same thing, however, the display is shifted so that one quarter of the total radar scan, that is 90° of azimuth is displayed over the entire display. Once this task is completed, the scan-to-scan averaging program is run and the following illustrations will provide some indication as to its effectiveness.

The program called SCANAV takes a number of scans and averages them in order to eliminate clutter and noise and enhance steady targets, resulting in an improvement in signal to noise ratio for the particular sector being processed. In our case of 5 or 6 scans are usually averaged, according to theory, a larger number of scans is preferable, however, we do not have the opportunity in the data set held to average more than 5 to 6 scans. In the illustrations shown, the pie shaped sectors are converted into a B SCAN format. This B Scan displays azimuth versus range information and it appears to be an extended rectangle. As can be seen, the raw data is presented in the top half of the illustration and the processed data is shown directly below on the bottom half of the picture. In this way, the raw data which has been reconfigured in shape only, can be directly compared with the results of the scan to scan processing applied to it, as shown in the bottom half of the picture. Once the scan averaging has been completed, other processing can be done to the resultant image.

FIGURE 2.2

Figure 2.2, which is the first in the series to be presented, shows the iceberg designated 1283 in the ESRF data collected aboard the SEDCO 706, and is displayed using the program VERIFY. It is an X band, long pulse display showing the inner ring of four concentric rings which were recorded. Ring 1 displays data out to a range of approximately 13.5 nM. The ships head is up and north appears at a relative bearing of 45° to the right of ships head. As can be seen, there is a large amount of clutter presented in the data and the targets of interest are not readily visible.

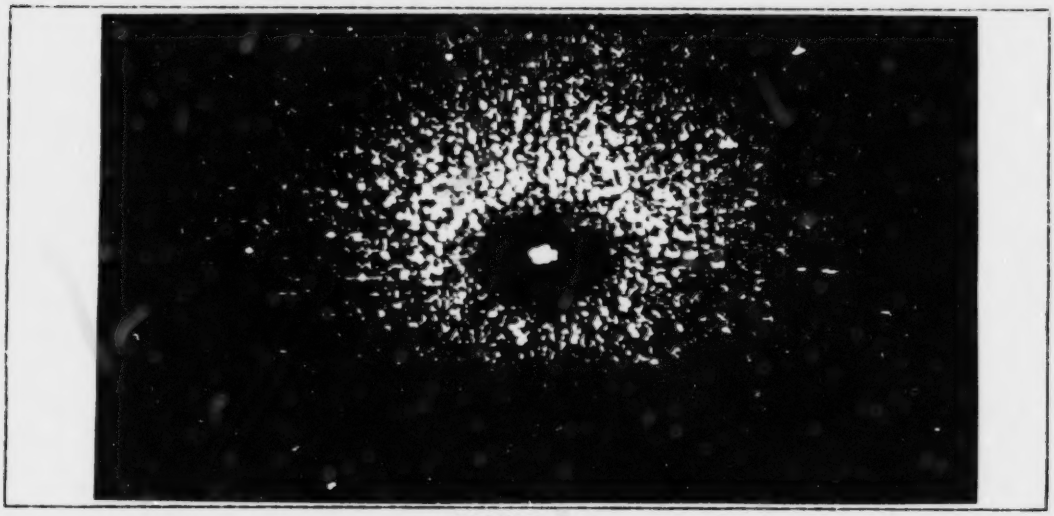


FIGURE 2.3

Figure 2.3 illustrates an S band long pulse radar. The information shown here is the same information recorded in Figure 2.2. Again, there is a great deal of noise, although there are two iceberg targets in the lower right portion of display.

FIGURE 2.4

Figure 2.4 is an example of the program J SCAN used to reformat data. Here the lower right quadrant has been blown up and redisplayed, and still the two targets of interest are very difficult, if not impossible, to pick out of the noise and clutter.

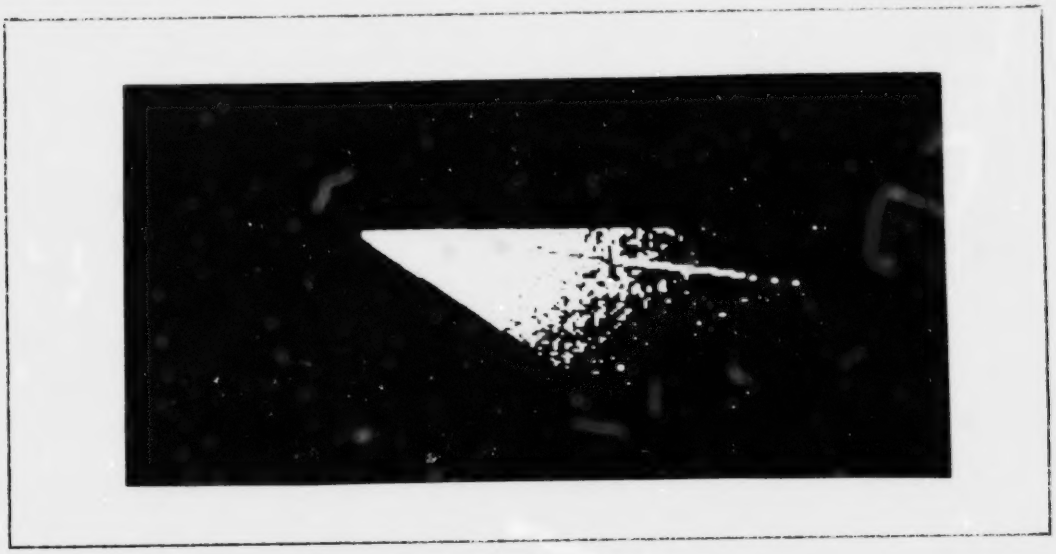


FIGURE 2.5

Figure 2.5 shows a further reformatting of the data using the M SCAN program. The targets of interests lie roughly in the vicinity of the cursor which is shown as a long narrow white line.

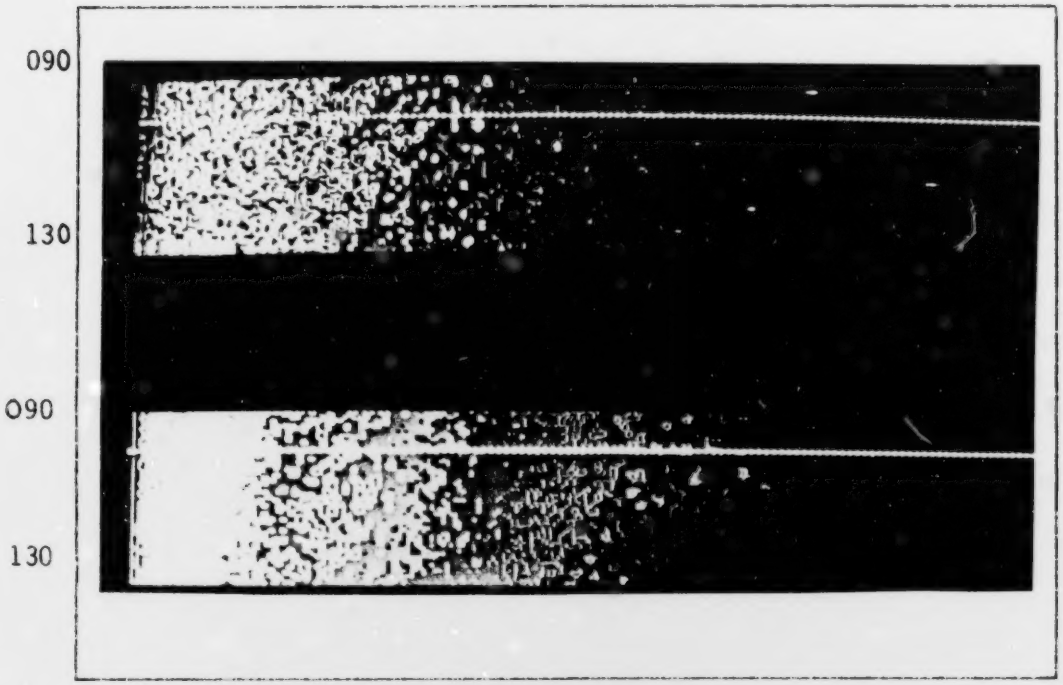


FIGURE 2.6

Figure 2.6 illustrates the previous reformatting of the M SCAN data in the top half of the slide. Here the B SCAN display referred to earlier is shown with the cursor as a long horizontal line sitting approximately 2° to the left of the two icebergs which are visible as two blue dots in the center of the M SCAN display. The white dots along the bottom indicate the distance in nautical miles and on the vertical axis, we have a bearing which changes from 90° at the top of the display to 130° at the bottom, thereby showing a 45° sector from a range 0 at the SEDCO 706 and extending out to a distance of approximately 13.5 miles away. The bottom half of the figure shows the first iteration of the program called SCANAV described earlier. Here the results of averaging five scans are shown and although the results are not overly impressive, the two icebergs are now very prominent in the display, and with persons having had some sort of experience with this type of presentation it is very easy to pick out the icebergs. As can be seen, the signal levels of the clutter close in to the rig and proceeding out to approximately 6 nM are still very heavy. It is considered necessary to remove this clutter. It also appears that there might 3 - 5 other targets out beyond 6 nM, however, due to the pixel width of these targets, it has been learned from experience that they can be considered noise.

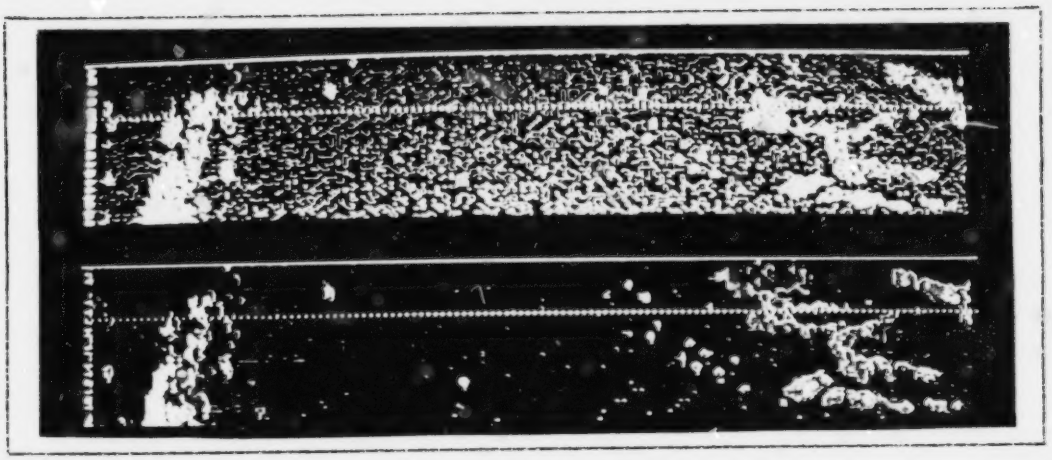


FIGURE 2.7

Figure 2.7 shows the result of averaging a number of scans of Remotec event AG 06. This is an X band recording and we are looking at a 45° segment of data, again ranging out to 13.5 nM. What we see in the top half of the display, where only raw data is presented, is a large amount of clutter fairly close to the ship at a range of .5 - 2 nM. Then we see two very large iceberg targets, one at approximately 3 miles and one at approximately 5 miles and further out at about 8 - 10 nM we see a field of smaller icebergs. At the extreme right of the presentation we see land. In the bottom display, the results of scan averaging are presented. Much of the noise displayed in the upper half of the illustration has disappeared leaving only clutter, two icebergs at 3 and 5 nM and the remaining field of icebergs at 8 - 10 nM. This particular scan averaging process used a total of 4 scans.

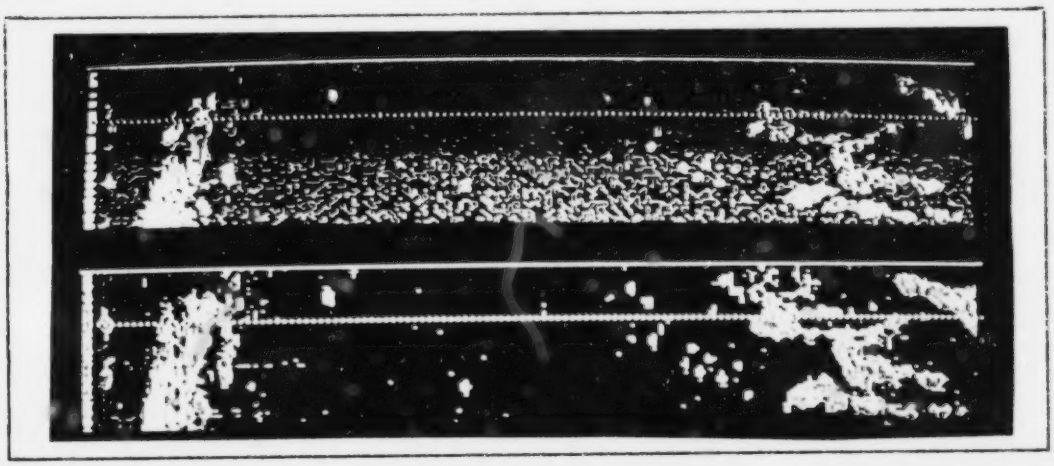


FIGURE 2.8

The following illustration, Figure 2.8, illustrates scan averaging with 6 scans. Here an even smaller amount of noise is present.

Another event, Remotec event BM-01 is a very appropriate event to conduct signal processing as it is full of very small targets, the majority being bergy bits and growlers.

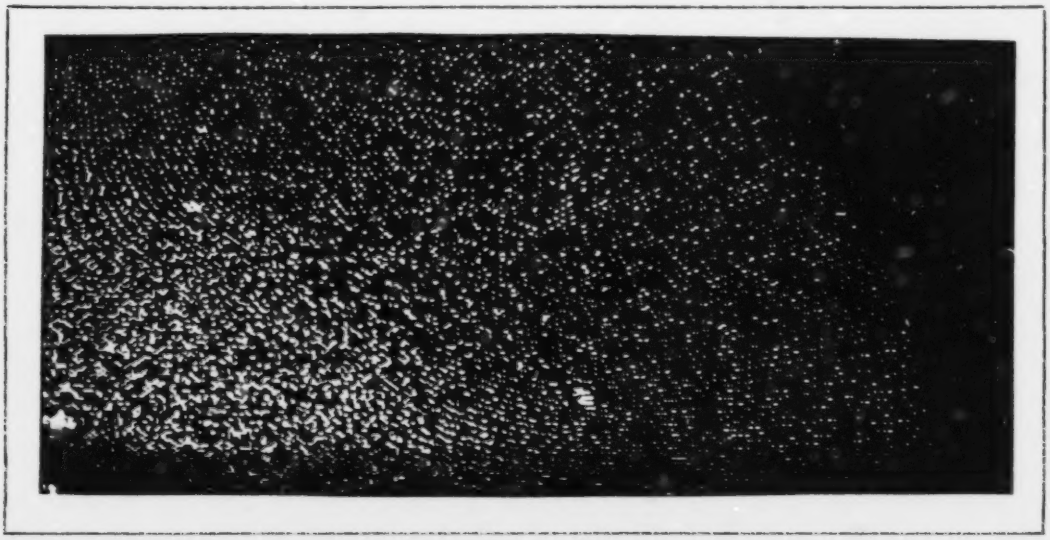


FIGURE 2.9

Figure 2.9 is a display of one quarter of the raw data using the J SCAN format, followed by Figure 2.10 which shows the opposite quadrant of raw data. In this particular quadrant, there is a great deal of land at the extreme ranges with a large number of bergy bits and growlers in the intermediate ranges.

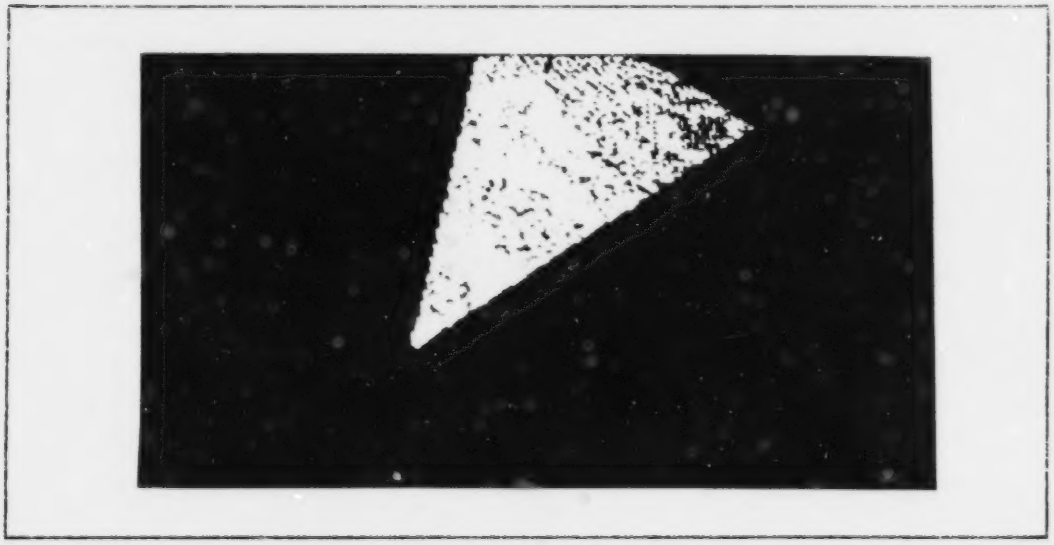


FIGURE 2.10

Figure 2.10 shows the M SCAN display reformatting the data for processing.

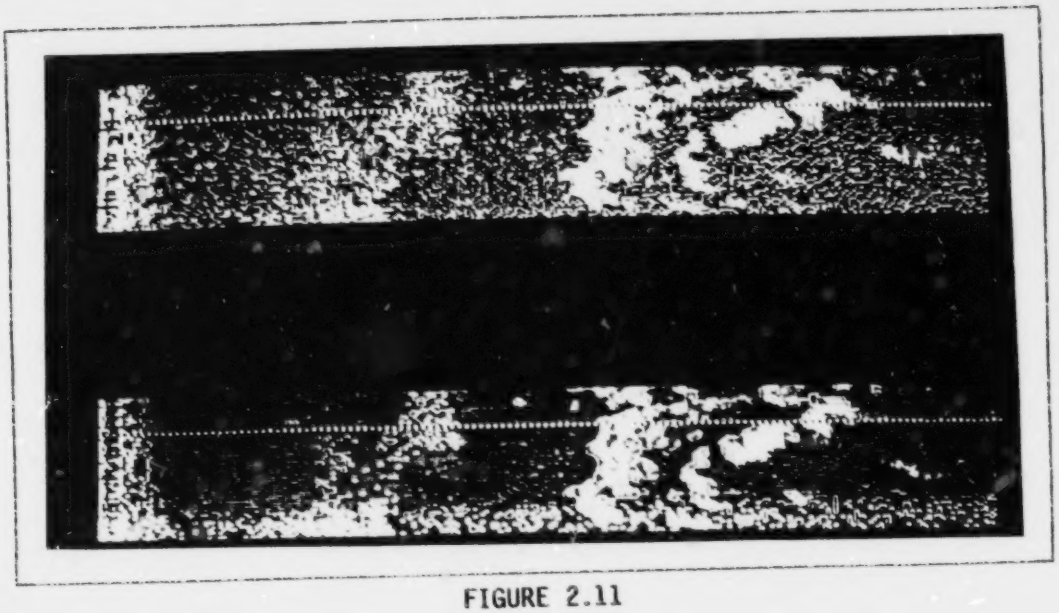


FIGURE 2.11

Figure 2.11 illustrates on the bottom half of the slide the resultant running a scan averaging program over only 4 scans. As can be seen, a certain amount of noise if effectively removed after these 4 scans have been averaged.

FIGURE 2.12

Figure 2.12 illustrates scan averaging after 6 scans and here, even more of the noise is removed. Scanning of up to 32 scans is desireable and if this were done, it is highly probable that there would be very little noise remaining. Unfortunately, only 6 scans have been recorded and it is impossible to average more than this.

Remotec target AD-10, utilizing radar X2, is the last of the scan averaging illustrations shown. There are no icebergs readily apprarent in the raw data.

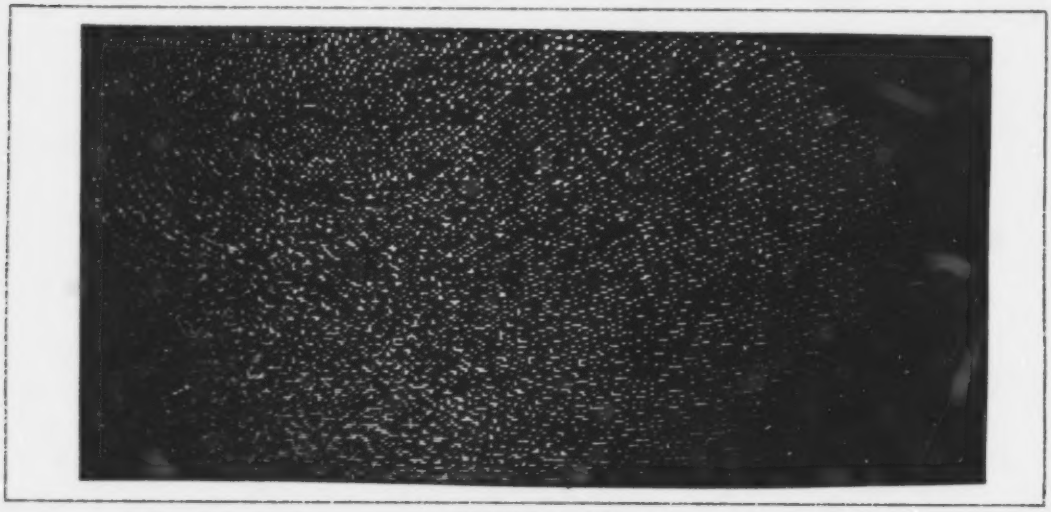


FIGURE 2.13

Figure 2.13 illustrates the J SCAN presentation on a bearing of 180° to 270°.

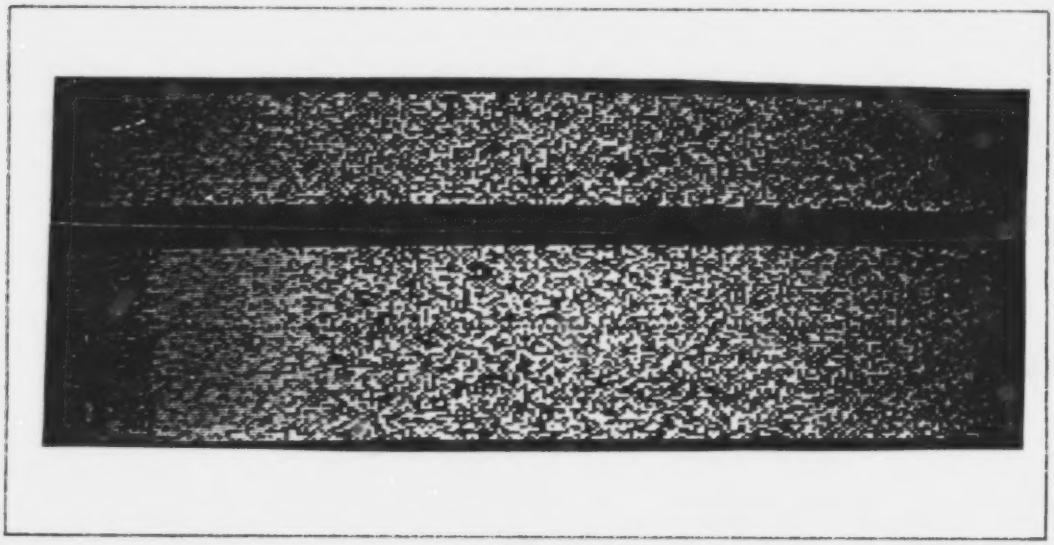


FIGURE 2.14

Figure 2.14 illustrates the data selected on a bearing of 200° to 250° in the B SCAN format. Raw data is again shown in the top half of the illustration. As can be seen there are no obvious targets in the data. After only 3 scans the resultant in the bottom of the illustration indicates the presence of several large targets. A large amount of random noise has been eliminated.

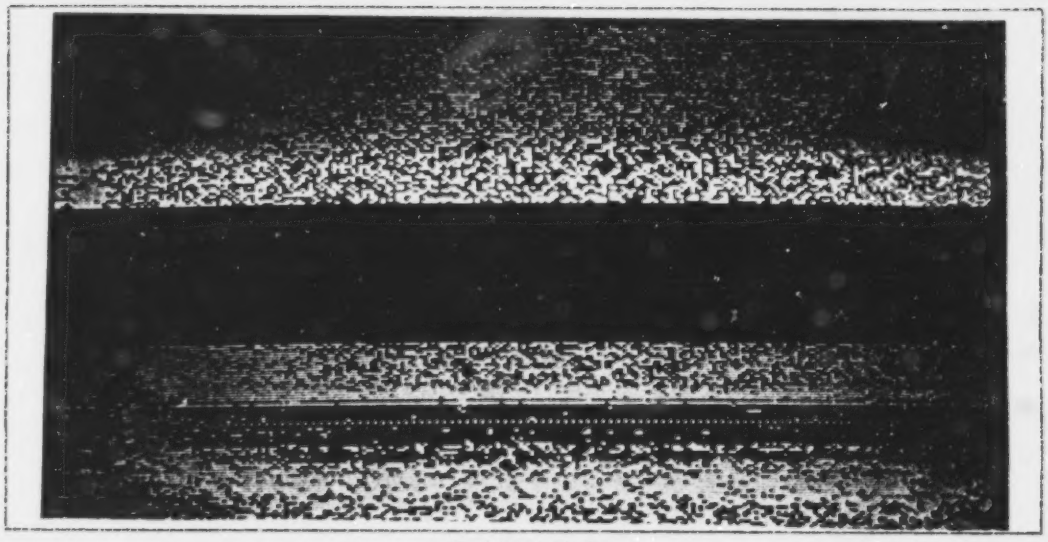


FIGURE 2.15

In Figure 2.15, 4 scans have been averaged. Unfortunately, in the bottom half of the resultant, a large amount of interference is displayed. If this is disregarded, we concentrate on the upper half of the image. We can see that virtually all of the noise has been removed leaving 5 large iceberg targets.

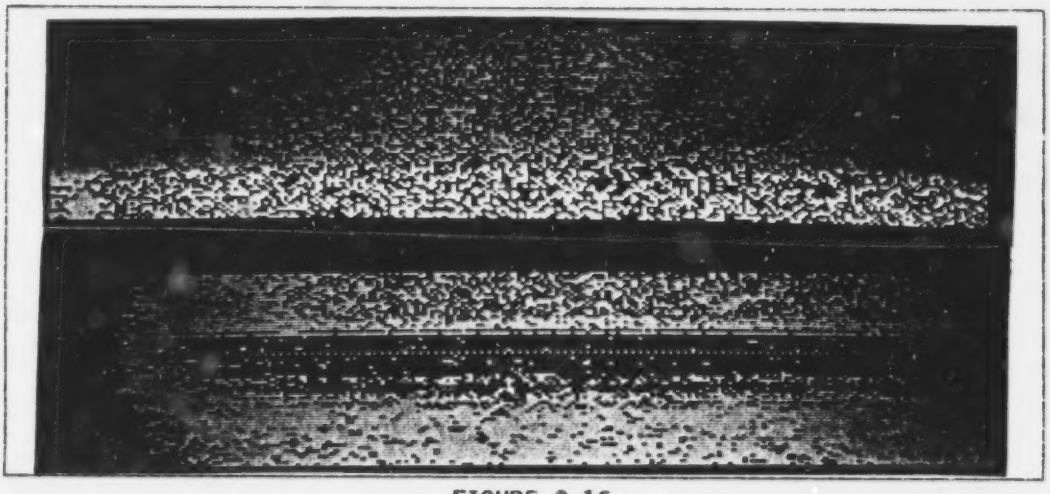


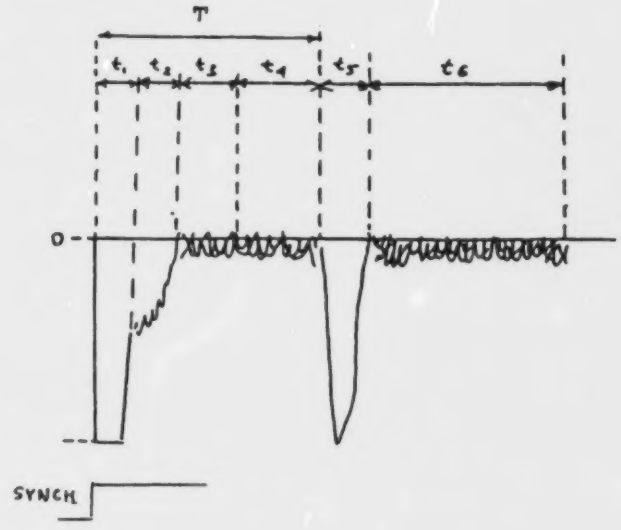
FIGURE 2.16

The last slide in this series, Figure 2.16, illustrates the resultant of averaging 5 images. Even the interference is shown in the previous figure, Figure 2.15, has been removed from this image. Again, most of the noise is removed from the top half of the image leaving only the icebergs. Comparing the results to the top half, or the raw data, it is easily seen that this is an effective processing technique.

Here we have demonstrated the basic process of scan averaging, a small number of scans on a small collection of targets. These averaging techniques form the basis of other techniques that can be implemented subsequently. One technique which we have utilized is the threshold processing technique. This will be discussed in the next section.

2.3.3 Methodology Dynamic Threshold Processing

The output of a radar receiver is a video signal which, when displayed on a short time base range, resembles Figure 2.17 below.



T - total ship - target measured distance.

t_1 - end of transmitting pulse.

t_2 - receiver circuit recovery time.

t_3 - dead part of observation zone (dependent upon antenna height, characteristic and target size).

t_4 - nearest target ship position which is possible to measure.

t_5 - width of useful pulse.

t_6 - longest range possible.

Figure 2.17 - Radar Video Signal

The incremental period t_3 and t_4 are important components of this signal. The t_3 component represents the noise and clutter component, which varies from scan to scan as a result of ship pitch and roll. If this part of the signal is electronically separated as a sample and the true RMS value of the noise and clutter amplitude calculated, then this noise and clutter level can be subtracted from the useful part of composite signal ($t_3 + t_4 + t_5 + t_6$). This will leave a video signal with an artificially higher signal to noise ratio.

As the clutter levels change, so must the threshold cutoff level, hence the requirement for dynamic threshold processing.

For detection of large targets this can be a desirable operation, however, depending at what stage of the processing sequence this takes place, small targets in noise and clutter may be lost.

In our case, threshold processing was undertaken after other processing techniques. It was normally implemented in order that the level applied could be recorded, however, automatic implementation would be relatively simple. The process was software driven in order to test its usefulness. A hardware based dynamic threshold processor could be fairly easily implemented after its usefulness has been determined.

An operational dynamic threshold processor might be implemented as an analog device to be utilized prior to digital signal processing. This would have the advantage of leveling radar video from different radars, thus improving the ability of an analog to digital convertor to properly assign digital signal levels to input voltages. The disadvantage here, as mentioned earlier would be that target signals in noise or clutter might be completely lost if they were below the RMS noise level that was being thresholded out. For this reason, if other processing schemes are to be utilized it is advisable to undertake dynamic threshold processing as one of the last processing steps. This would take advantage of the increased signal strengths of targets and the concurrent reduction of noise levels enabling a threshold level to be chosen that minimizes target loss on the display.

Threshold processing also permits the filtering of targets below a certain radar cross section. This would be of interest to ice capable ships travelling in bergy bit and growler infested waters that wanted to disregard smaller targets. This case is demonstrated in the next section.

2.3.4 Results Dynamic Threshold Processing

As was stated in section 2.3.3, threshold processing enables a filtering of targets below a certain radar cross-section. This capability could be utilized as a sort of classification technique by ships officers and marine crew on board drilling rigs to determine the potential threat of icebergs that have been detected.

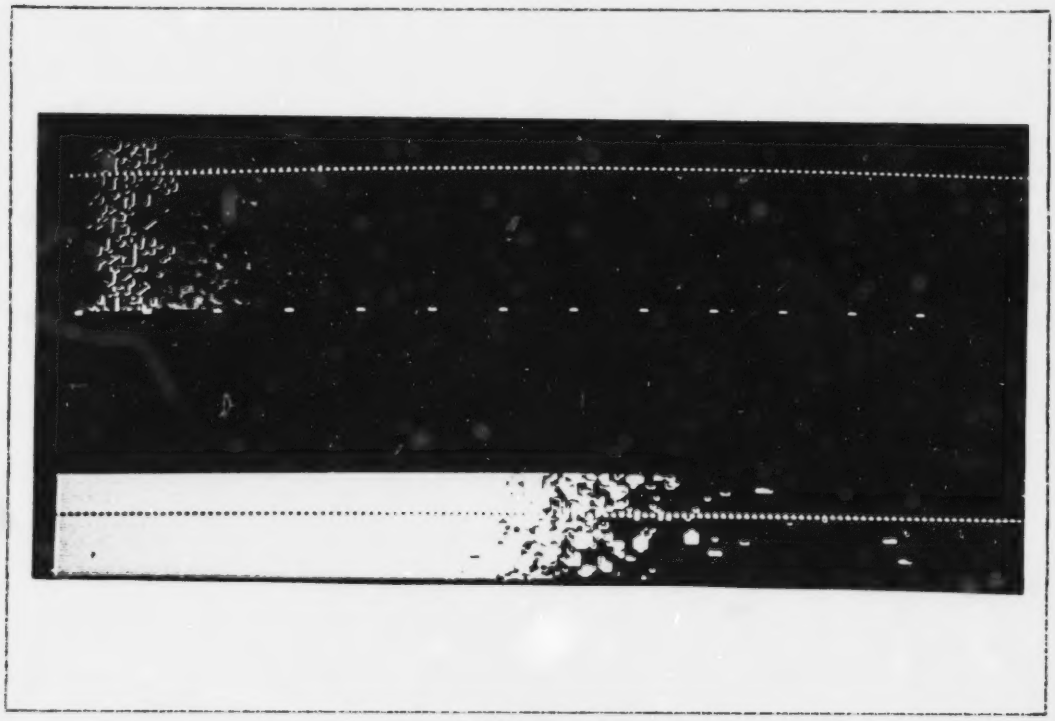


FIGURE 2.18

In Figure 2.18, the first run through on the thresholding process is utilized on iceberg 1283 collected aboard the SEDCO 706. The thresholding program is called SNR and a total of 64 levels can be selected. All data above a certain level will be yellow or white. At around the threshold level of interest, data will be coloured either blue or red, red being the higher of the two levels. Below the threshold levels of interest the pixels will appear black indicating no target interest. In Figure 2.18 the threshold levels are set very low and as can be seen in the bottom half of the slide, not much of the noise has been removed, it has simply been changed in colour for better visual presentation. However, the two icebergs which used to be two prominent blue dots in the center of the display, are now very bright yellow dots.

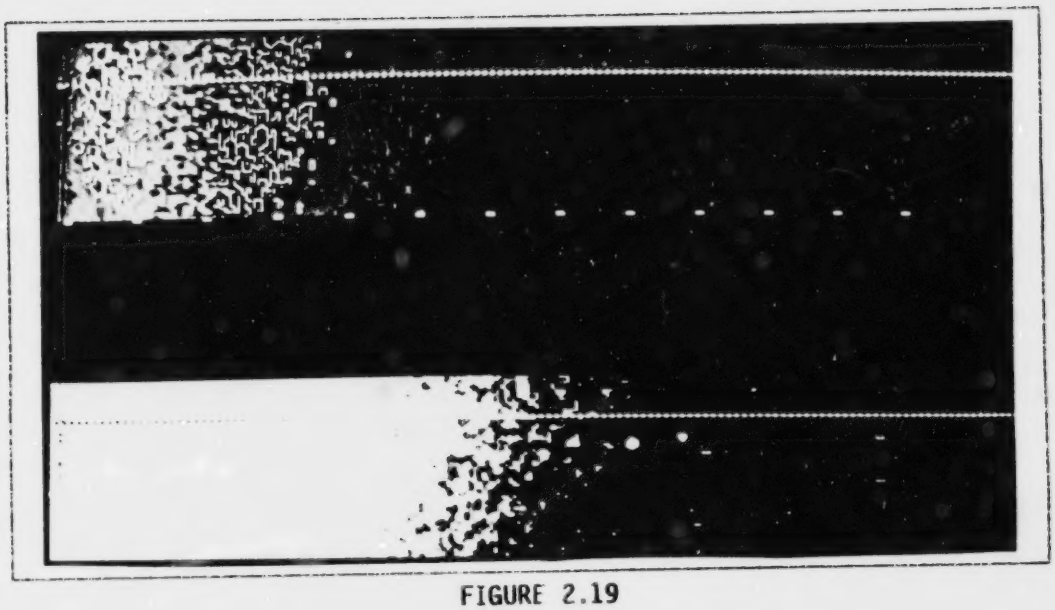


FIGURE 2.19

Figure 2.19 illustrates a raising of the threshold, marginally eliminating some of the clutter on the fringes of the clutter ridden area. The icebergs on the bottom half of the display can be seen to be quite prominent when compared to the product of the scan averaging program displayed in the top half of the slide

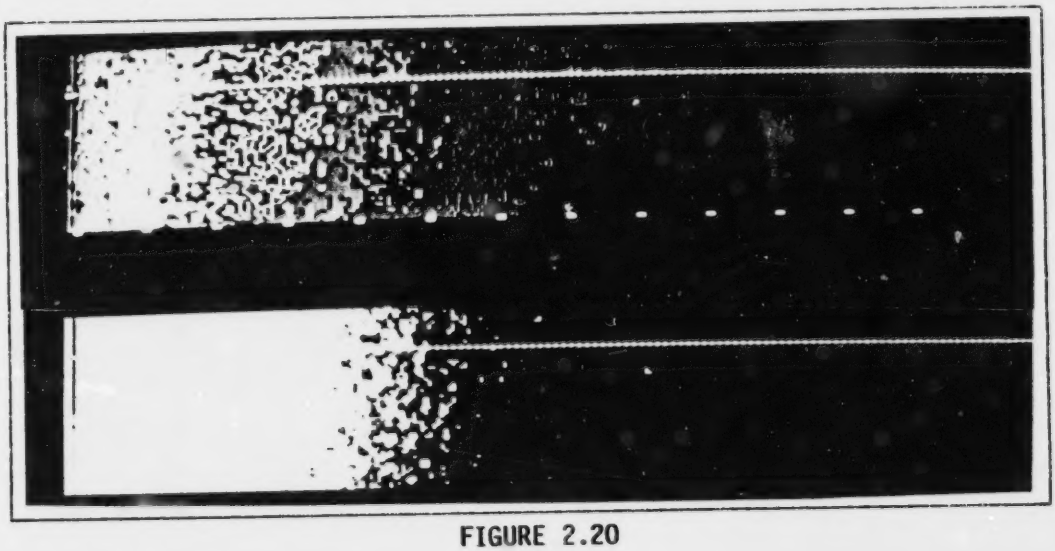


FIGURE 2.20

Figure 2.20 demonstrates the final product of the thresholding program showing one fairly prominent target at 8 nM below the cursor. Another iceberg has been thresholded out, however, a new target appears to have emerged just above the cursor at a range of 6.4 nM. With a different adjustment of the threshold, and should be possible to display all three of these targets.

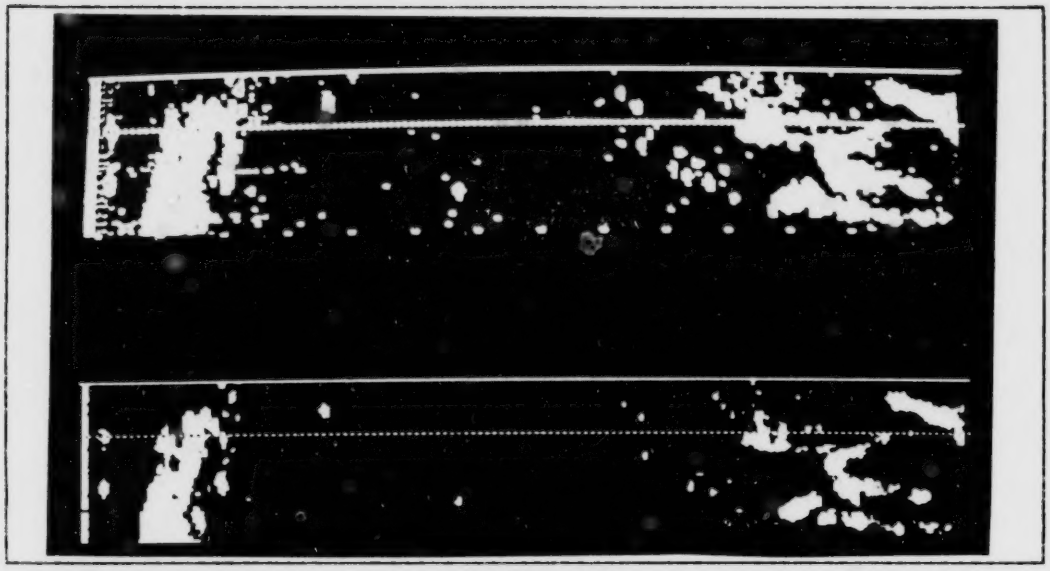


FIGURE 2.21

Attempting the SNR program on Remotec event AG-06, we see in Figure 2.21 the scan averaging resultant and the upper half of the figure is modified considerably in the bottom half when SNR is utilized. What we have left at the bottom of the figure is a very prominent iceberg target and prominent iceberg fields nearer to land and the only interference that we are left with is the clutter relatively close to the ship.

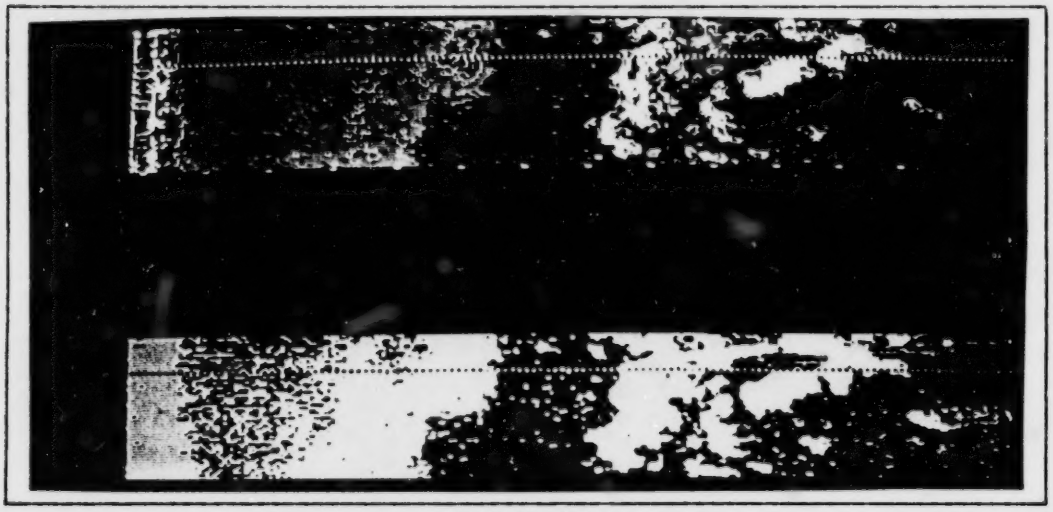


FIGURE 2.22

Remotec event BM-01 is again illustrated in Figure 2.22 where the thresholding techniques is applice once again. Here a very low threshold is applied and we can see where the blue area is displayed in the middle of the bottom presentation, it would appear to be fairly safe for ship navigation.

FIGURE 2.23

Figure 2.23 raises the threshold somewhat and what is displayed is a large quantity of ice and icebergs represented by blue and white dots at further range just above the cursor. In the middle of the bottom display, we see a very large iceberg and to the right we see the land mass.

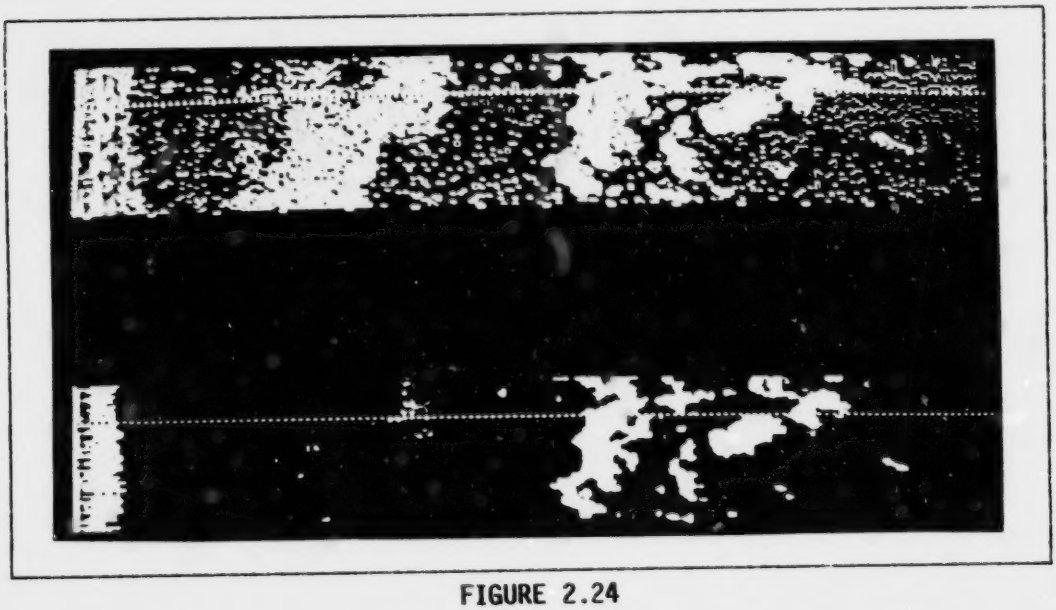


FIGURE 2.24

Figure 2.24 raises the threshold even further and we effectively have eliminated all of the noise leaving only a small amount of clutter very close to the radar itself shown on the left, effectively displaying a large quantity of icebergs, presumably growlers and bergy bits.

Raising the threshold even further, which might be desirable from an icebreakers point of view, not particularly concerned with bergy bits and growlers, we have only left some of the larger bergs in particular the very large one at mid range. This process can be continued where we gradually reject the smaller targets, leaving only the very largets of targets, illustrating the possibilities of target discrimination for vessels such as icebreakers or icebreaking tankers which might not be concerned with the smaller targets. This technique could also be utilized aboard offshore oil exploration and production units to form an input into their iceberg management systems.

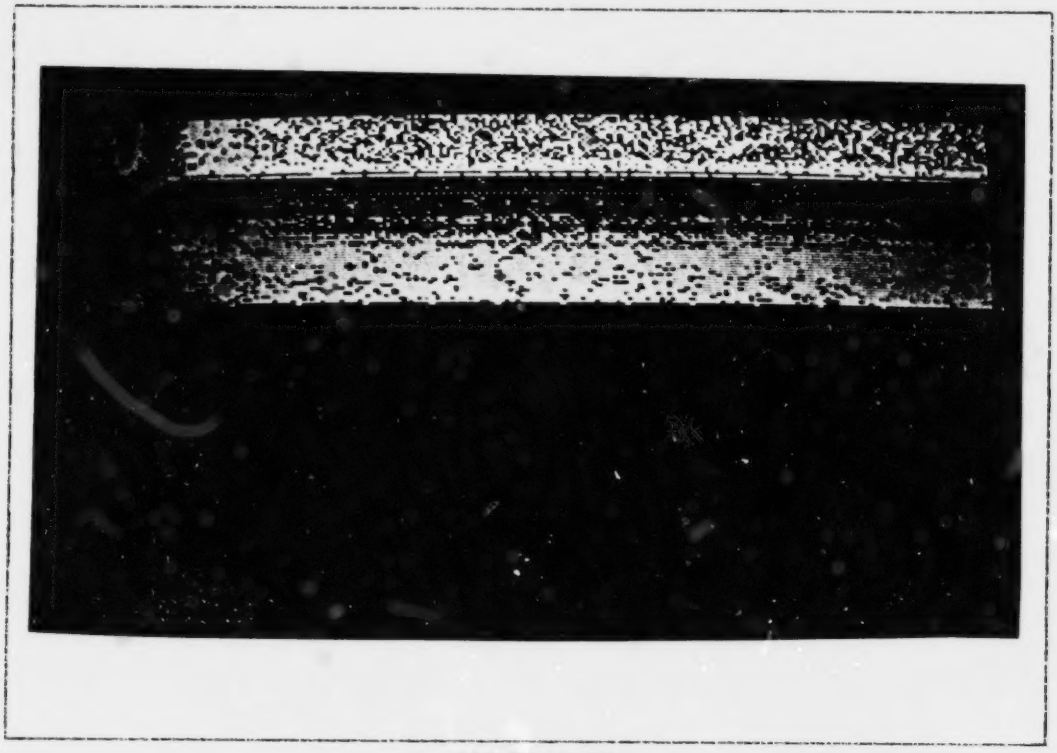


FIGURE 2.25

Figure 2.25 illustrates a implementation of the SNR program on the averaged result of target AD-10. Here the threshold is set at level 38 and much of the noise has been thresholded out leaving a very prominent display of larger icebergs in the top portion of the SNR resultant.

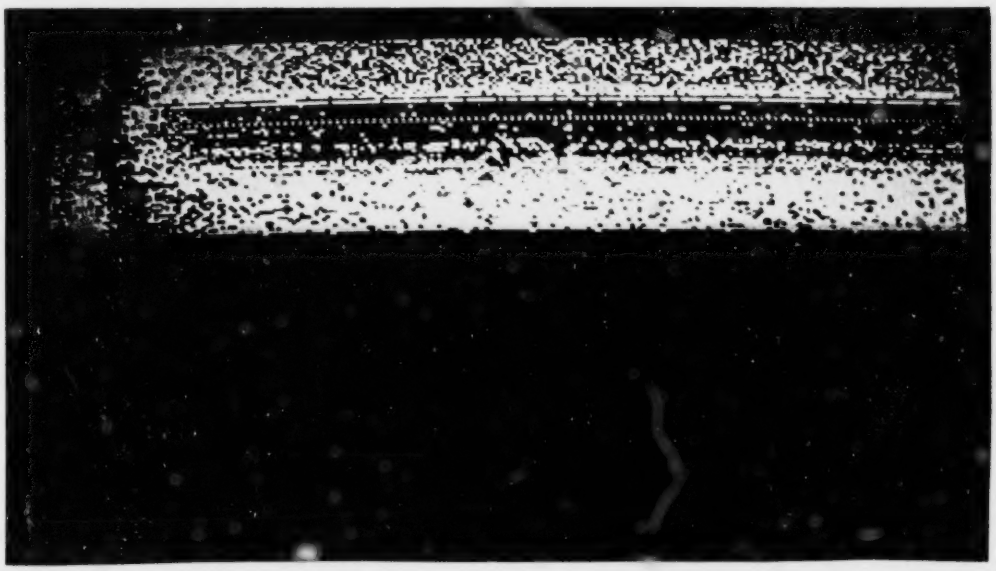


FIGURE 2.26

In Figure 2.26 the left threshold is raised to level 43 and all of the noise has been thresholded out. Only the very close range sea clutter remains, and even the system generated noise in the lower portion of the SNR display is gone. We are left with three very large iceberg targets shown in red and two smaller targets displayed in blue. Again this is an effective classification technique.

2.3.5 Methodology Statistical Processing

If the signal reflected from an iceberg is much larger than that reflected from the surrounding sea clutter, then the detection of this target is simply a matter of setting the appropriate threshold. If on the other hand, the signal strength returned from the wanted target is of the same order, or perhaps even smaller than the sea clutter, then a severe detection problem exists. The obvious solution to the problem is to average the signal.

The system developed by McGill, and installed on SEDCO 706 by Viatec, has the advantage that it can record, on digital magnetic tape, the intensity values for each range bin at each azimuth for each rotation. A major purpose of the experiment was to evaluate the extent to which digital image processing can improve the detectability of ice targets. This section will describe the theory on which the experiment was based.

When the radar returns are obtained from ocean waves there are generally many reflections from different parts of the wave system. These returns add in random phase. If the distribution of the amplitudes from each of the separate scatterers is reasonably distributed (ie. there is not one reflection much bigger than all the rest) then the resulting distribution is the well-known Rayleigh distribution which has the form.

$$P(x) = \frac{2x}{(x^2)_{AV}} \cdot \exp\left(-\frac{x^2}{(x^2)_{AV}}\right)^{-1}$$

If, on the other hand, the reflections are dominated by one return, either from a target embedded in the sea clutter or from one seawave reflection that is much stronger than the rest, the result is a Rice distribution which has the form.

$$P(x) = \frac{1+S}{x_{AV}} \exp\left[-S - \frac{x}{x_{AV}}(1+S)\right] I_0\left(2 \cdot \sqrt{\frac{x}{x_{AV}} \cdot S(1+S)}\right)^{-2}$$

where S = Signal-to-noise ratio

I_0 = the modified Bessel Function of zero order

A computer program has been written which generates random numbers having any specified distribution. The result of generating 1000 Rayleigh and 1000 Rice distributed random numbers are shown in Figures 2.28 and 2.30 respectively.

If it is assumed that clutter exhibits a Rayleigh distribution and clutter plus signal exhibits a Rice distribution then the detection problem is equivalent to drawing a single threshold which will distinguish between the clutter only (Rayleigh) and clutter plus signal (Rice) data. Even a casual inspection of Figures 2.28 and 2.30 show that this cannot be done for the data shown.

With investigation of this type it is useful to use discriminant functions to measure the skill of the threshold in distinguishing the target of the types incorporated into Bayes Decision Theory approach to Artificial Intelligence. Consider two distributions of the types shown earlier and sketched below:

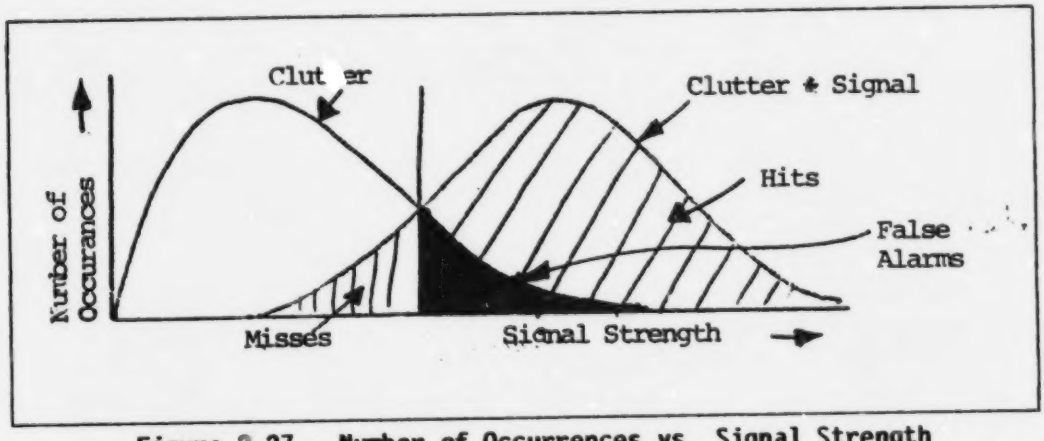


Figure 2.27 - Number of Occurrences vs. Signal Strength

The discriminant functions which may be used in this type of anaylsis are:

Critical Success Index (CSI) = Hits/(hits + misses + false alarms)

False Alarm Ratio (FAR) = False alarms/(hits + false alarms)

Probability of Detection (POD) = Hits/(hits + misses)

For a Perfect Technique CSI & POD = 1
and FAR = 0

For theoretical curves of clutter and clutter plus signal, these functions may be calculated exactly as the size of the signal increases. The more interesting calculation of the discriminant functions as the number of data averaged increased. These distributions cannot be readily calculated analytically. The form of the distributions may be obtained from the random number approach mentioned earlier. The results of averaging 2, 4, 8, 16, 32 and 64 samples for both the clutter and clutter plus target case as illustrated in Figures 2.28, 2.29, 2.30 and 2.31. Comparison of corresponding pairs of distribution will reveal that the skill of the threshold, which was negligible for single data points steadily increases until when we average 64 data points the two distributions have become sufficiently narrow that the two distributions have been almost completely separated. This would imply that averaging 32 or 64 signal returns from a target with a cross section rather less than the variance of the cross section sea clutter is sufficient to give very high probability of detection.

A further question which may be addressed using this data set is the relative merits of complete averaging, of the type already shown, compared with exponential averaging of the type frequently employed in radar systems. In this latter course the signal for the first data set is put into a store (shift register or delay line) when the second data set arrives the first is removed from the store added to the new data, divided by two and returned to the store. This is continued for as long as the averaging is required. The result of averaging 2, 8 and 64 in report samples for the clutter and the clutter-plus-target data is shown in Figure 2.32 and Figure 2.33. It may be seen that after an initial improvement actually up to N=4 no further improvement is obtained. This is because the effect of the averaging is such that the variance of the last data point is not reduced. Indeed, it is found that there is absolutely no point in going beyond N=4 for this type of procedure. This would suggest that in the design of digital radar processors the averaging must be performed in the complete manner - the averaging procedure commonly used in the pulse-to-pulse system is very inefficient even accepting that the sea clutter signal strength is in fact independent on a pulse-to-pulse basis.

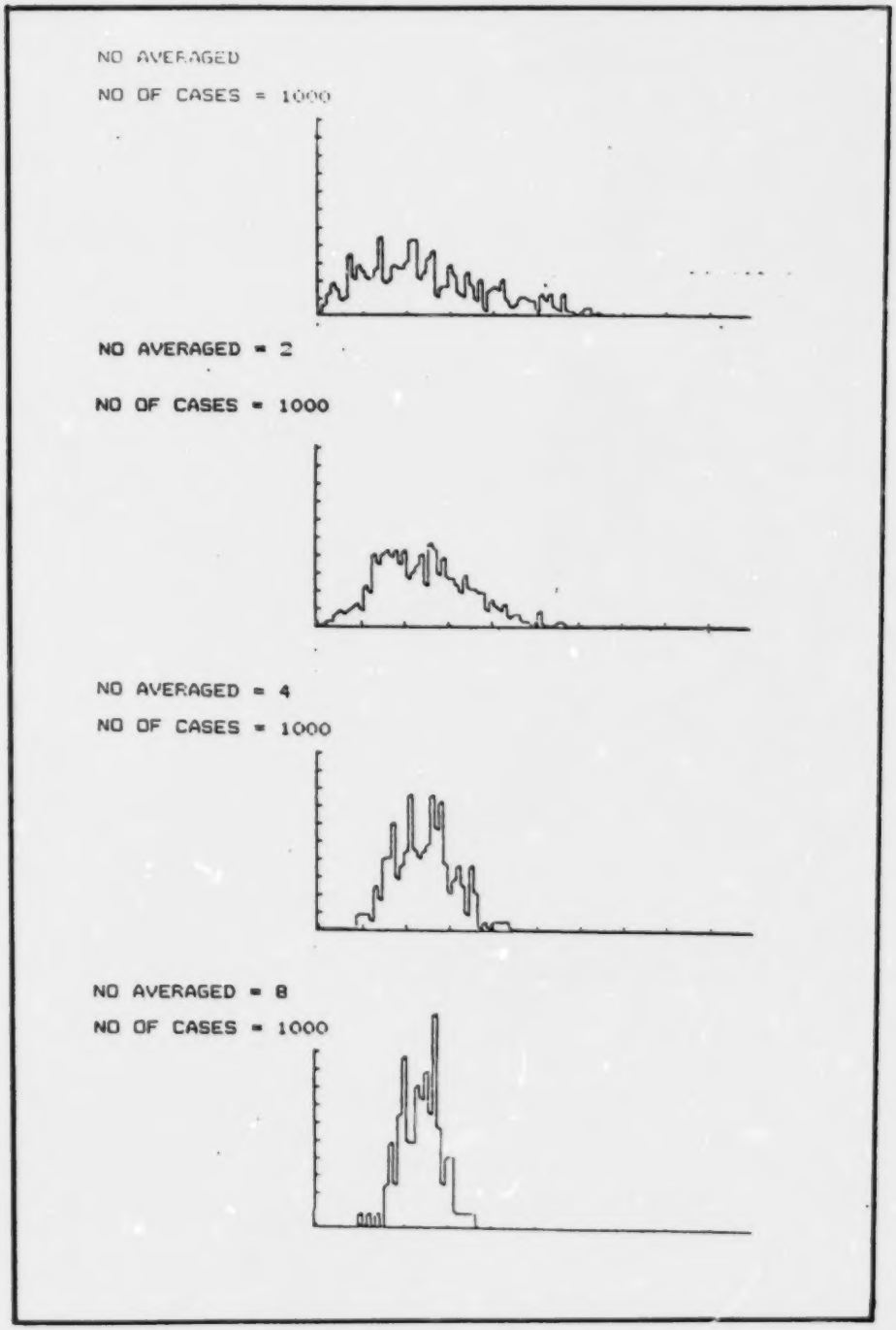


FIGURE 2.28 - CLUTTER ONLY - AVERAGED

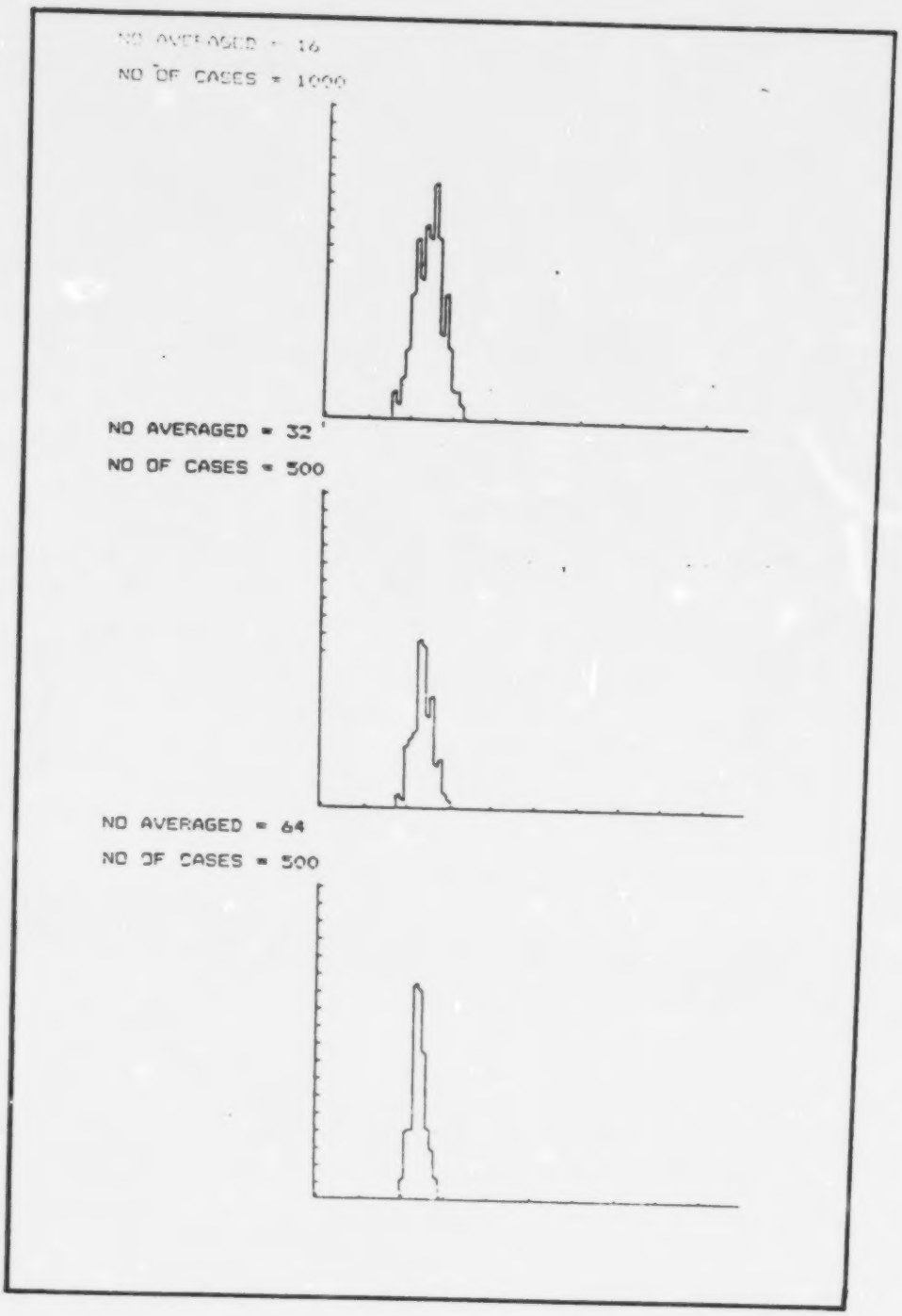


FIGURE 2.29 - CLUTTER ONLY - AVERAGED

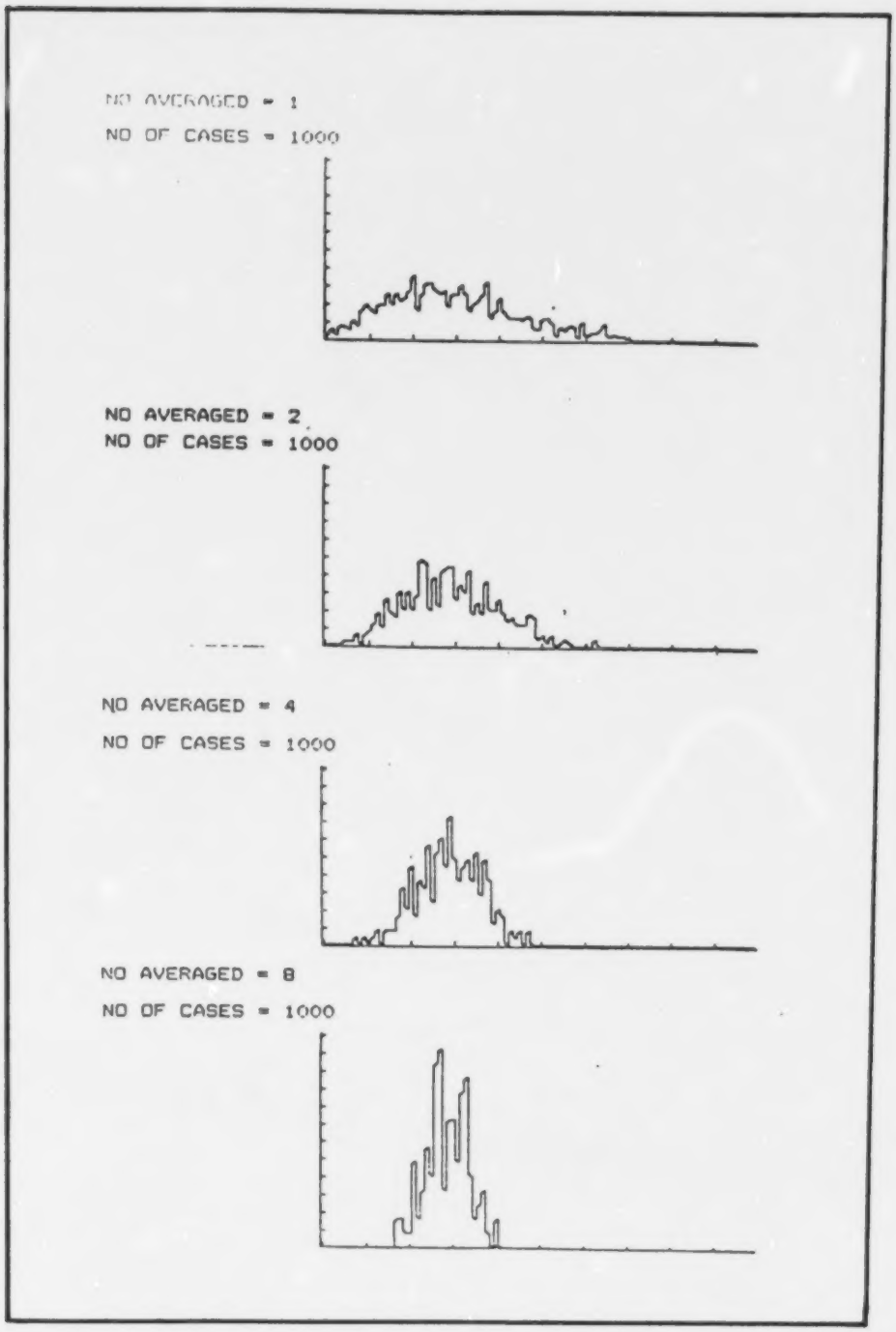


FIGURE 2.30 - CLUTTER AND SIGNAL - AVERAGED

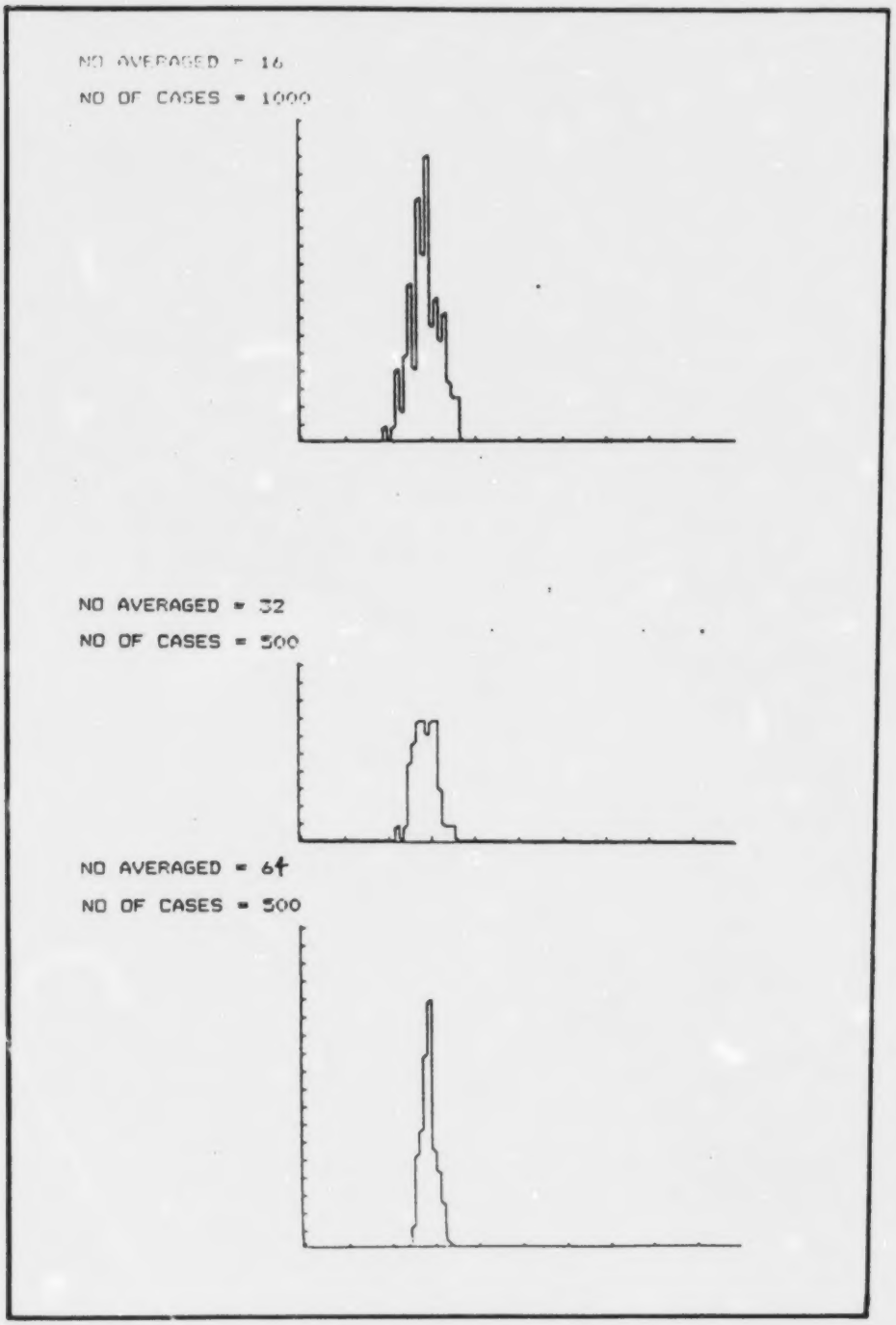


FIGURE 2.31 - CLUTTER AND SIGNAL - AVERAGED

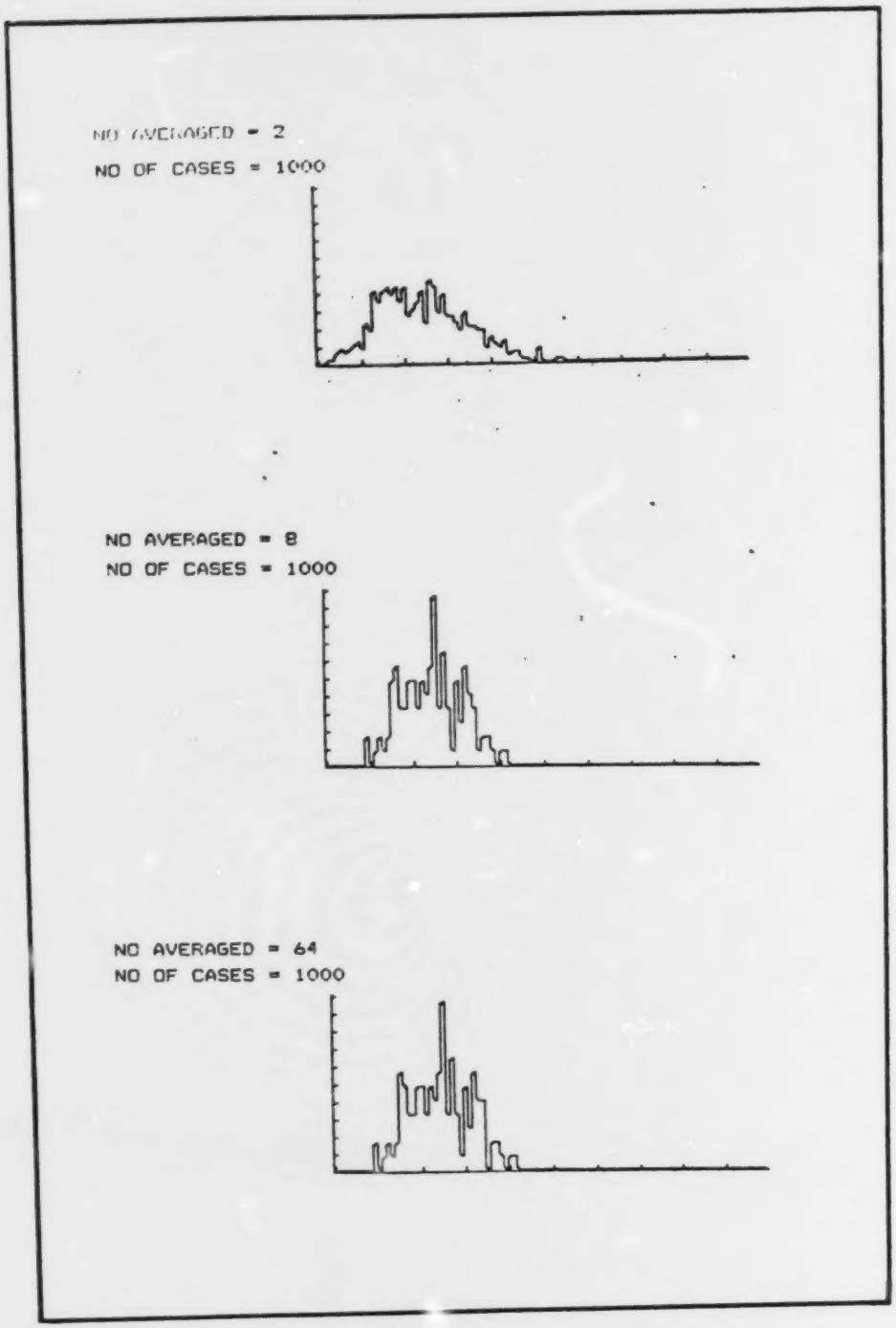


FIGURE 2.32 - CLUTTER ONLY - EXPONENTIAL AVERAGED

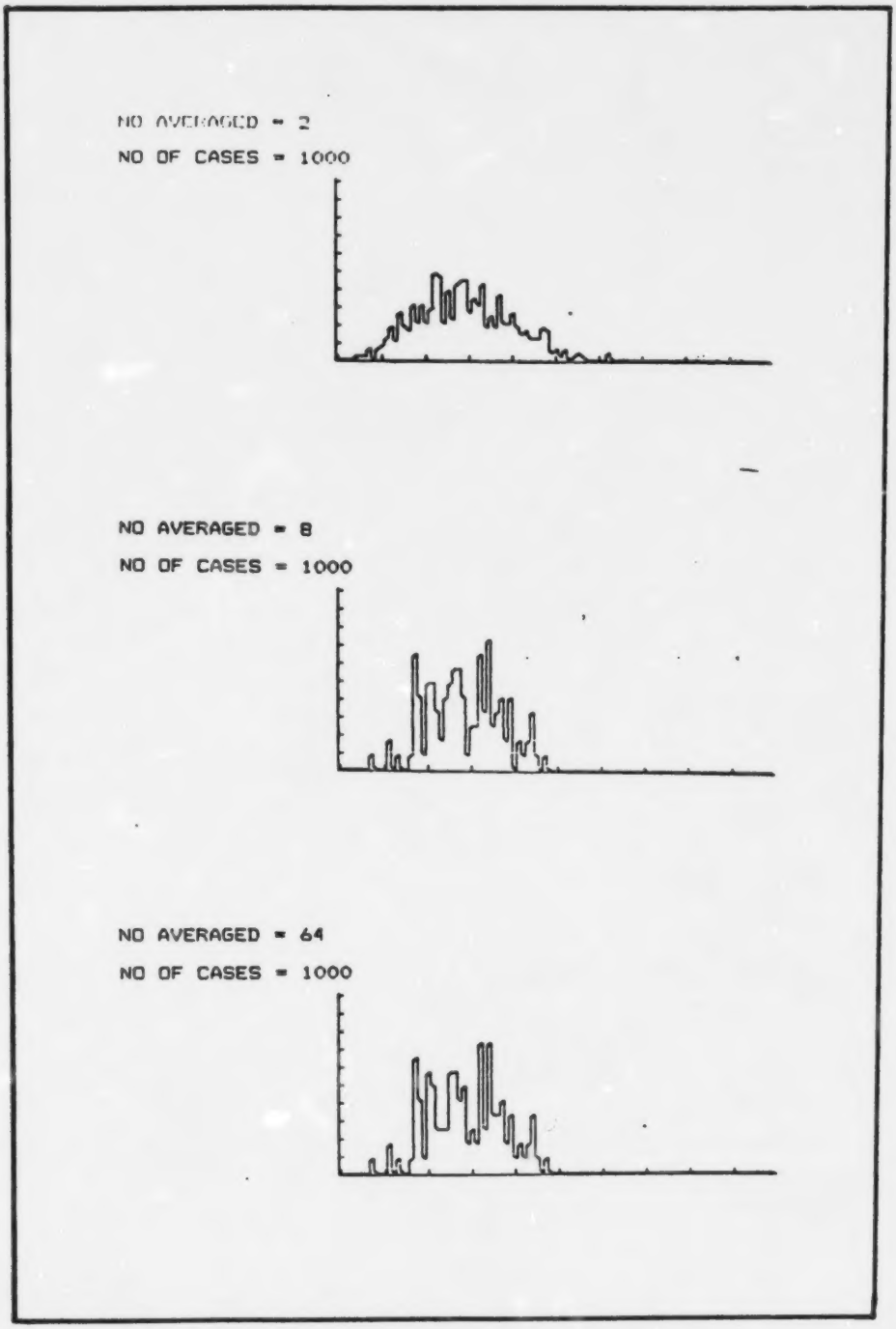


FIGURE 2.33 - CLUTTER AND SIGNAL - EXPONENTIAL AVERAGED

2.4.6 Results Statistical Processing

We could proceed to calculate CSI, POD and FAR for the data presented in Figures 2.28 - 2.33 but we have to recognize that this data is not representative of the actual data from a marine radar looking at ice in sea clutter. The first reason for this is the fact that each data from sea clutter is often significantly different from a Rayleigh distribution having significantly more large values. The second reason is that the receiver employed in most marine radars is logarithmic, which has the effect of reducing the size of the tail to the large amplitude side of the mode and increasing it to the left. It thus becomes essential to use real data obtained from a field experiment to test these processing strategies.

Figures 2.34 (a)&(b) and 2.35 (a)&(b) show the distribution of approximately 30,000 data points obtained from 3 different ranges for the data digitized using the Remotec tapes and the McGill digitizer at Viatec. The first three are for sea clutter at ranges 1-2 km, the second 5-6 km and the third 9-10 km. It may be seen that the data is more symetrical than the Rayleigh distribution discussed above because of the log receiver used. As the mode decreases with increasing range the number of zero data points increases and becomes a spike as in Figure 2.35(a). When we look at a target as in Figure 2.35(b), we get a rather different picture where we have a large number of zero data - just outside the target and then a broad distribution of signal values going up to very high values.

We can now use a program which generates random numbers to the distribution function shown in Figures 2.34 (a)&(b) and 2.35 (a)&(b). This has the advantage that we can simulate an infinite number of rotations of the antenna not available in the original data set. This has been done and then curves similar to Figures 2.28, 2.29, 2.30 and 2.31 generated for different amounts of integration.

The results of this analysis can be expressed in terms of the CSI, POD and FAR as a function of the target signal strength above the mode of the clutter for different amounts of integration. The data resulting from the 5-6 km clutter set are shown in Figures 2.36 - 2.38.

The curves show the required signal strength and number of averaged samples to achieve various levels of target detection. The curves are probably reasonably self explanatory. The most interesting is probably Figure 2.38 where we can see for a given target signal strength, the number of samples which must be averaged to give various CSI's. For a modest 2 dB signal, for example, a CSI of as high as 0.99 can be achieved if 32 samples are averaged. This modest target signal would be totally undetectable in a conventional system. In general the drastic increase in target detectability as the number of samples is increased can be seen.

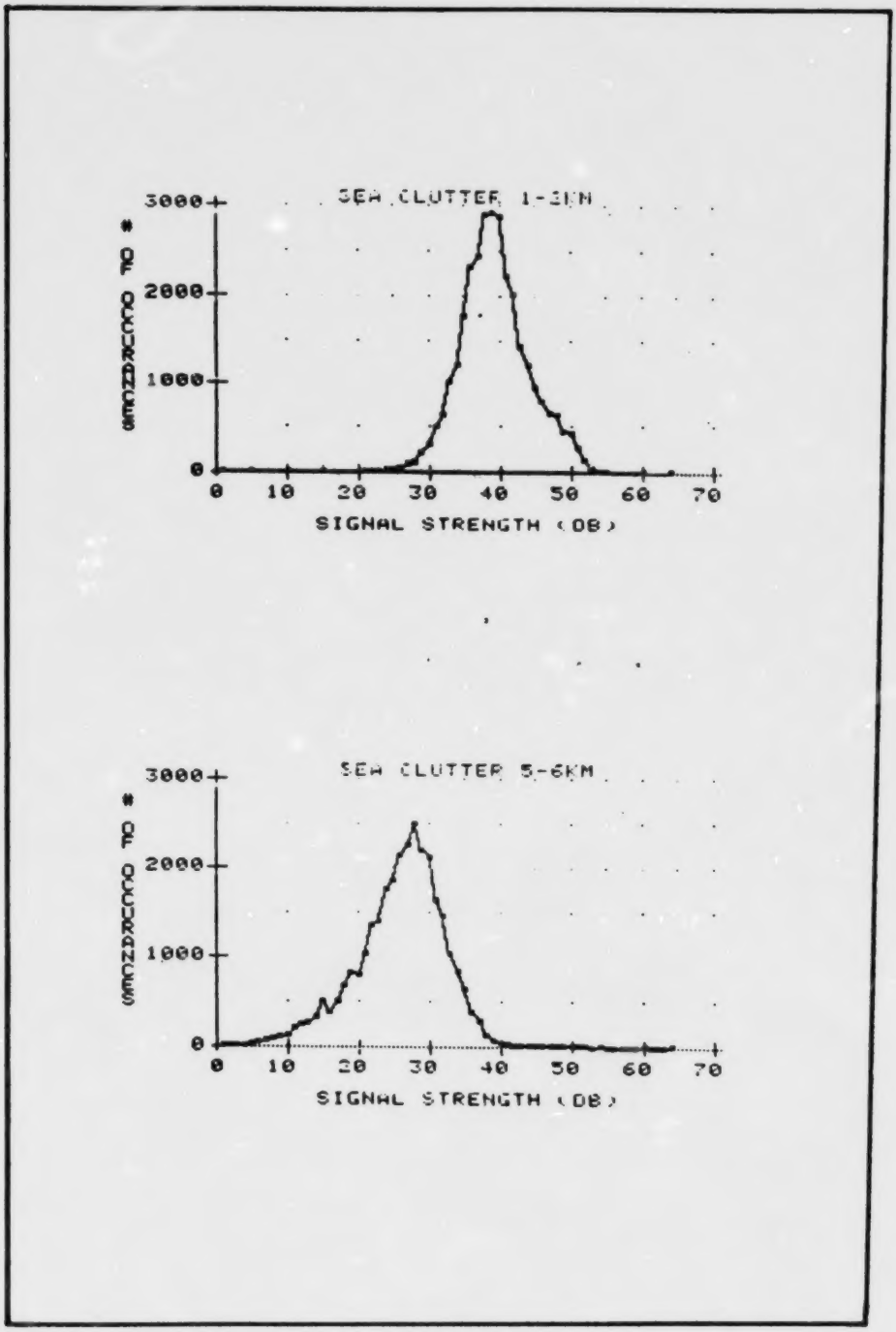


FIGURE 2.34 (a)&(b) - NUMBER OF OCCURRENCES vs. SIGNAL STRENGTH

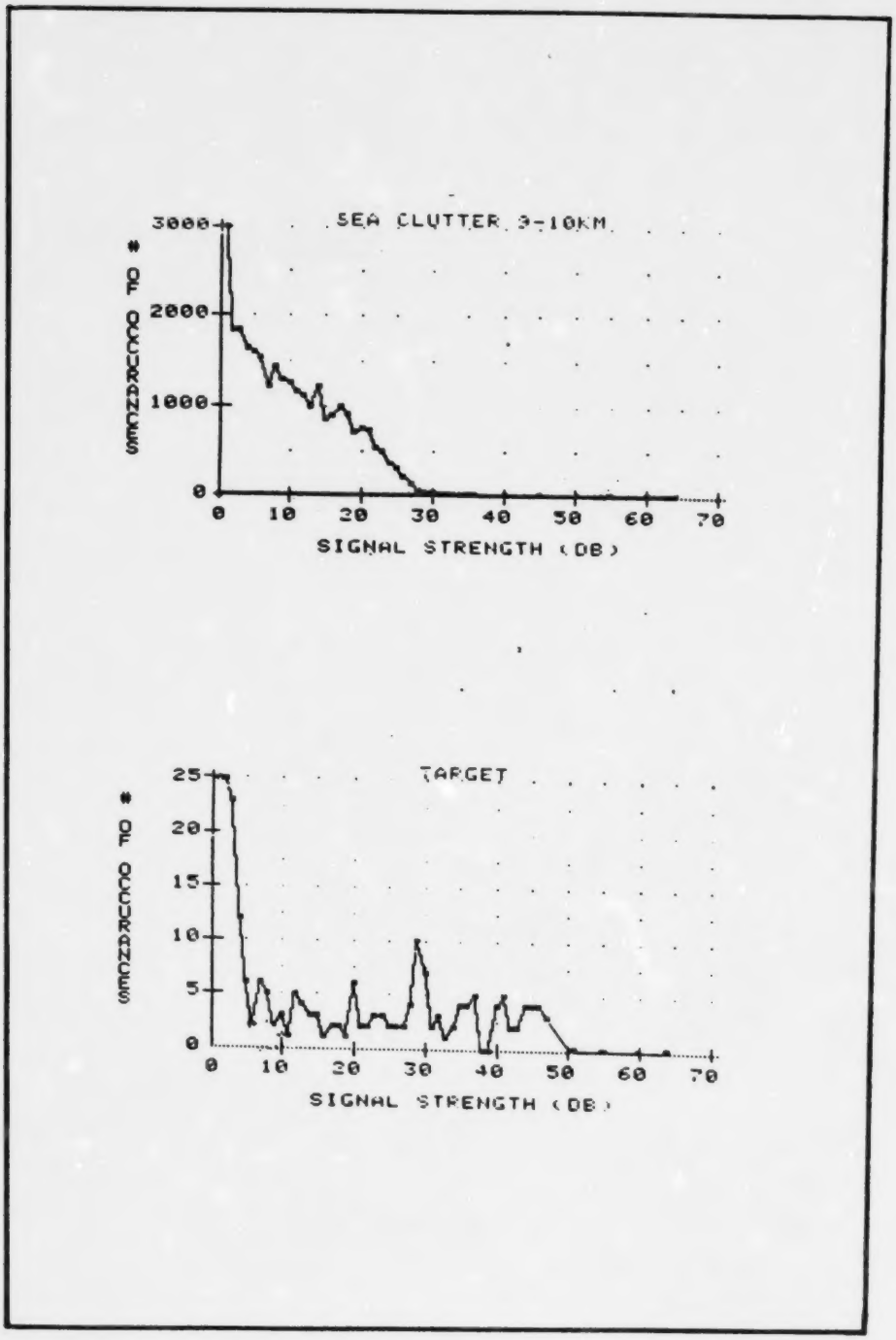


FIGURE 2.35 (a)&(b) - NUMBER OF OCCURRENCES vs. SIGNAL STRENGTH

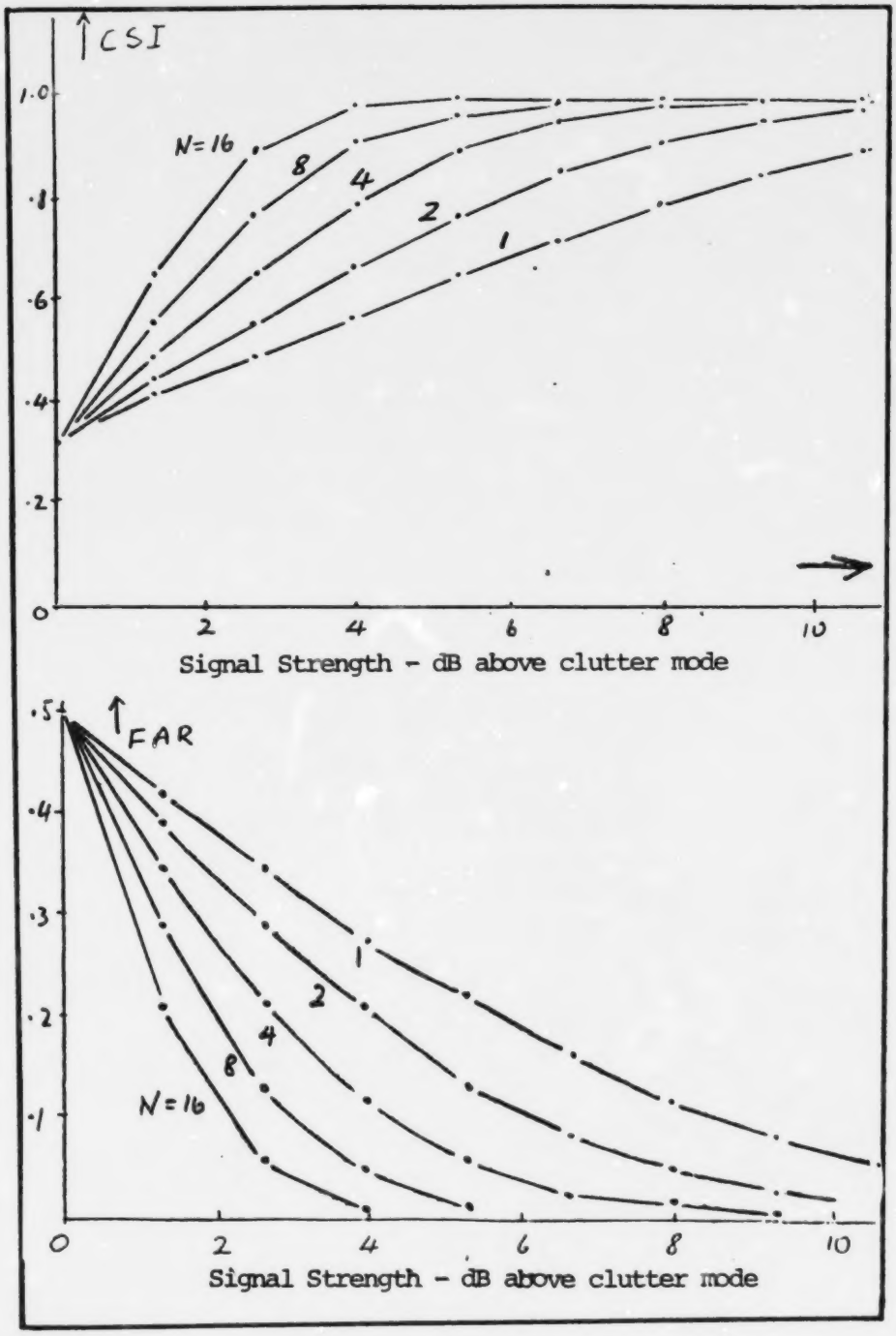


FIGURE 2.36 - CRITICAL SUCCESS INDEX vs. SIGNAL STRENGTH

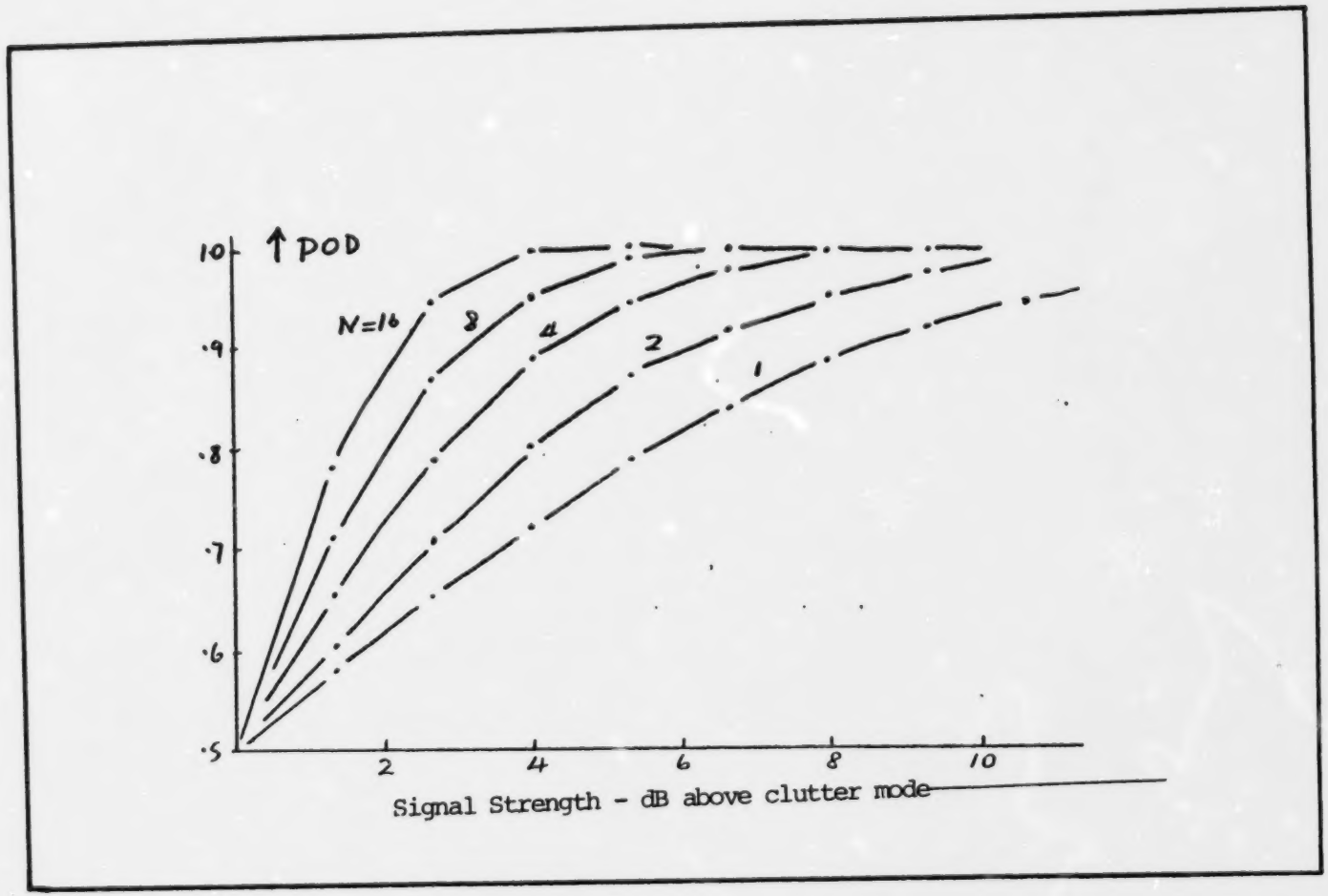


FIGURE 2.37 - PROBABILITY OF DETECTION vs. SIGNAL STRENGTH

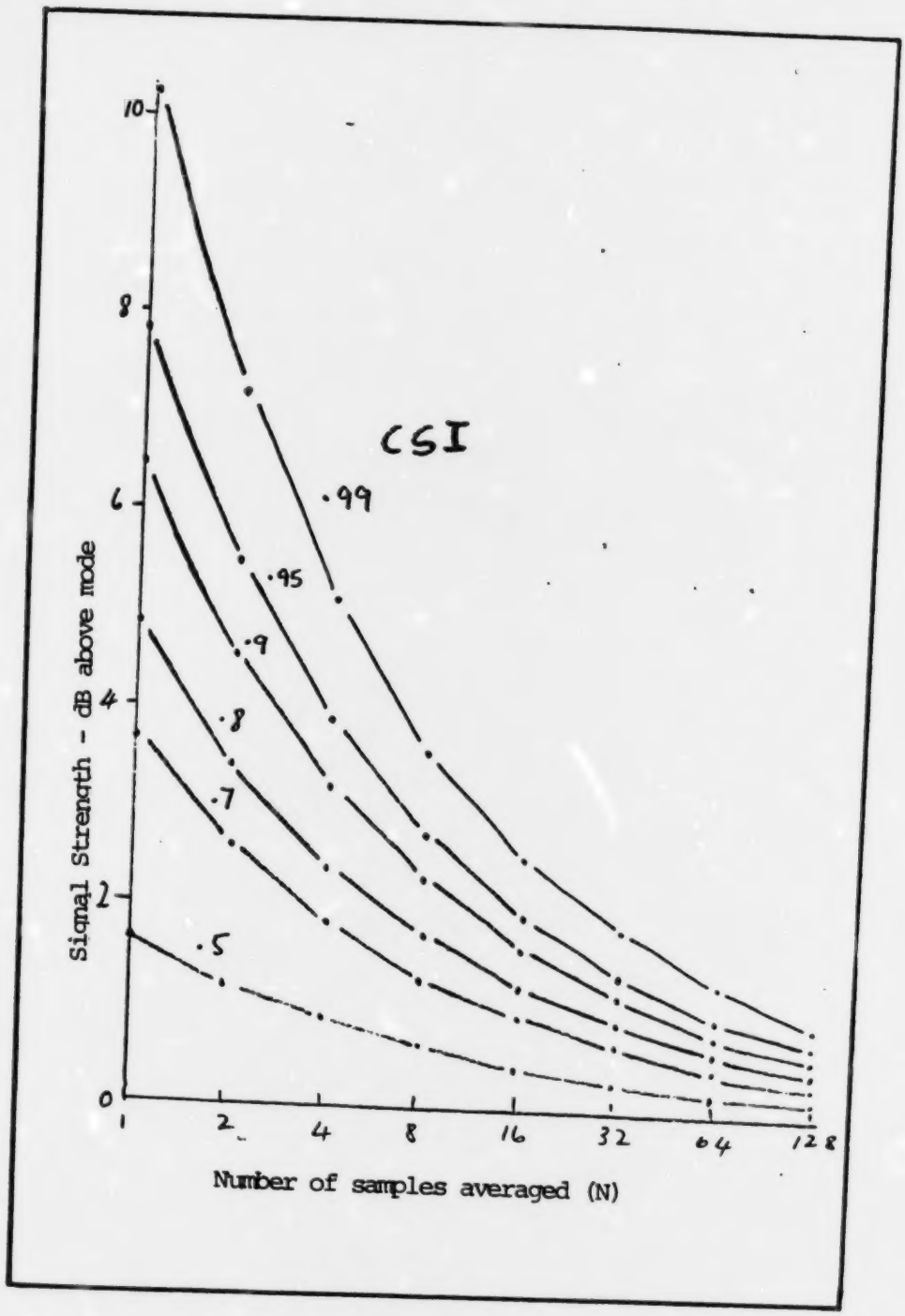


FIGURE 2.38 - SIGNAL STRENGTH vs. NUMBER OF SAMPLES AVERAGED

3.0 SYSTEM SPECIFICATION

3.1 Introduction

This specification describes a proposed Ice Hazard Detection/Collision Avoidance System (IHD/CAS). This system shall be used to collect and display ice and iceberg location data with inputs derived from a group of sensors.

The following documents of the exact issue shown, form a part of this Specification to the extent specified herein.

TP 4216 E	Feb. 83	Final Report	A Preliminary Specification for the Ice Hazard Dection/Collision Avoidance System.
MIL-STD-721	25 Aug. 66	Issue B	Definition of Effectiveness Terms for Reliability, Maintainability Human Factors and Safety
MIL-STD-781	Test Plan VC	Issue C	Reliability Demonstration
MIL-STD-810	10 Mar. 75	Issue C	Environment Test Methods
MIL-STD-210	15 Dec. 73	Issue B	Climatic Extremes for Military Equipment
MIL-STD-167	01 May 74	Type 1	Mechanical Vibrations of Shipboard Equipment
MIL-STD-108	04 Aug. 66	Issue E	Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment
MIL-STD-1399	10 Dec. 72	Issue A	Interface Ltd. for Shipboard Systems, Electric Power
MIL-STD-454	01 Mar. 76	Issue E	Standard General Requirements for Electronic Equipment
MIL-E-16400	24 Dec. 74	Issue A	Electronic Equipment, Naval Ship and shore; General Specification for Interior Communication and Navigation Equipment.

The IHD/CAS shall consist of an integrated display system and associated sensors and processor capable of displaying a wide range of sensor video and synthetic information. It shall include the following classes of sensors:

Radars
Frame Sensors (LLLTV)
Line Scan Sensors (I/R)

The display shall consist of a high resolution colour T.V. type display. Colour has been selected as preferable over monochrome due to the results of experiments conducted by C-Core and Gulf Canada Resources. A grey scale shading experiment did not yield as promising results as other advanced colour display techniques. The results of the trial indicated that Grey level definition is not vital to ice tracking. In addition, a "Daylight" video display makes radar more accessible to users of ice information. Control electronics, operator interface and pixel memory shall be included. The display shall interface with a general purpose computer which can be programmed by users for individual applications. These applications shall include ice management procedures and collision avoidance options.

The IHD/CAS shall consist of the following functional units which are illustrated in Figure 3.1

Sensors
- X Band Radar
- S Band Radar
- Ka Band Radar (if applicable)
- HF Radar (if applicable)
- Infrared (IR)
- Low Light Level Television (L.L.L.T.V.)

Interfaces
- X Band Interface
- S Band Interface
- Ka Band Interface
- HF Interface
- Computer Interface
- Display Interface
- High Speed Serial Interface
- Electrical Power Interface
- Television Interface

Display
- High Resolution Monitor
- P.P.I.
- Operator Control Unit

Computer
- Display Processor

Processors
- X Band Signal Processor
- S Band Signal Processor
- Ka Band Signal Processor
- HF Signal Processor

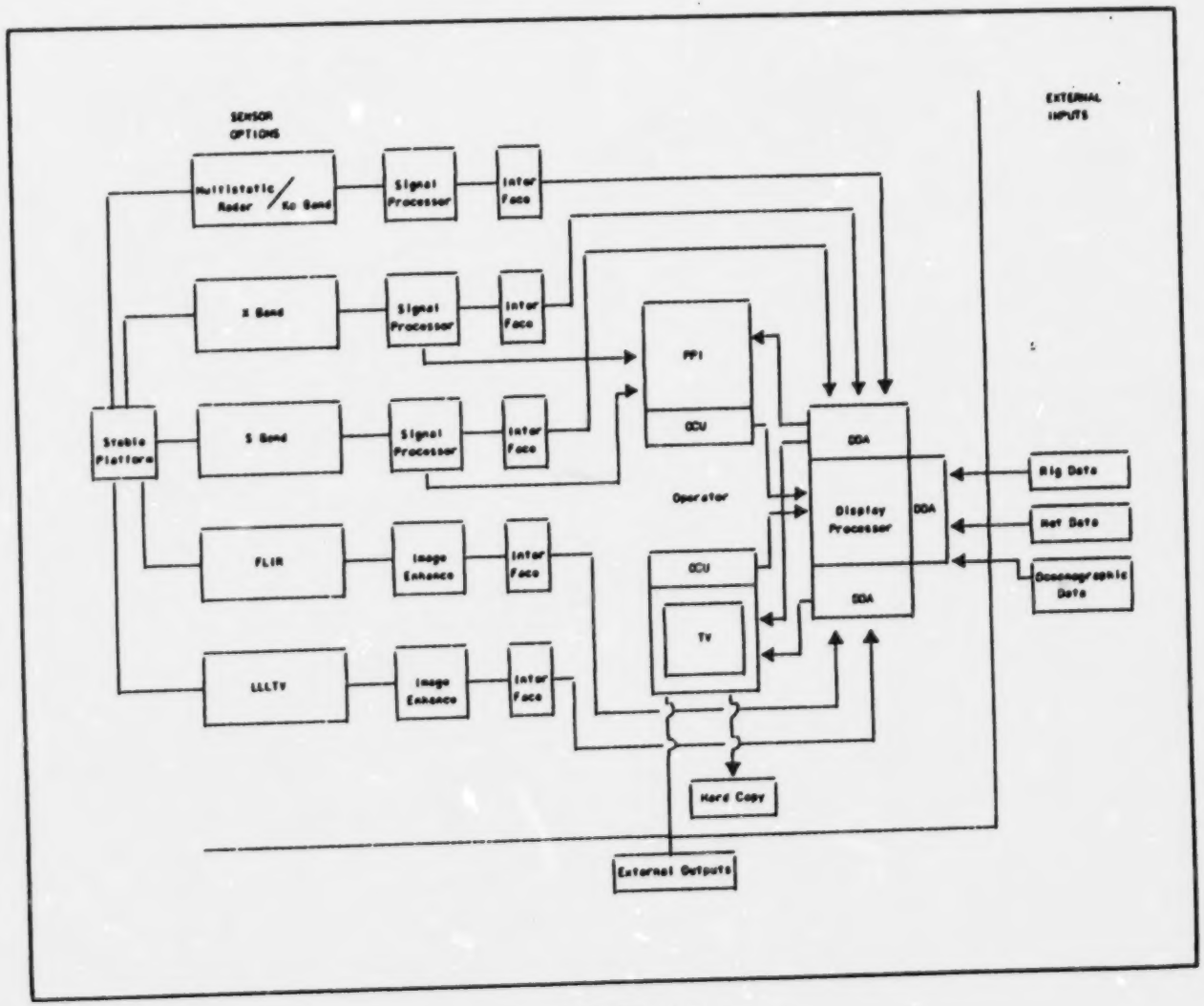


FIGURE 3.1

IHD/CAS BLOCK DIAGRAM

3.2 Sensors

3.2.1 X and S Band Radars

Both X and S Band radar are specified for their individual merits. The X-band radar is capable of finer spatial resolution and is capable of higher power levels near the ocean surface. X-band radar does suffer from signal attenuation due to heavy rainfall, and is prone to sea clutter problems. S-band radar has superior detection ranges due to lower frequency and generally higher power.

The following radars are specified as candidates for and IHD/CAS.

	Detection Range (km) Pd = .75 pfa = 10^{-6}	
	X Band	**S Band**
Raytheon	16	32
Japan Radio Co.	21	30
Japan Radio Co. Sea Ice Radar	31	
Furuno	19	
Sperry	25 Linear 14 Circular Polarization	
Racal Decca	29	31.5

Table 3.1
X and S Band Radar Capabilities [1]

1 Iceberg Detection Capability Part I, Newfoundland Petroleum Directorate Contract Report, 1983, p.9.

3.2.2 Radar Frequencies

X Band - 9400 MHz

S Band - 3050 MHz

3.2.3 Antenna

X Band - Slotted waveguide 9 ft.

S Band - Slotted waveguide 12 ft.

Speed of Rotation 22 r.p.m. nominal
20 r.p.m. minimum for wind speed up to 100 kts.

Both X and S band antennas shall be aligned on both vertical and horizontal axis.

Antenna gain - X Band - 32 dB nominal
- S Band - 26 dB nominal

3.2.4 Polarization

The depolarization radar signals by icebergs attributed to volume to scattering by air bubbles within the ice requires the use of a dual polarized antenna.

For both radars, horizontally polarized transmission shall be utilized and both X and S band antenna shall be capable of receiving both vertically and horizontally polarized signals.

3.2.5 Transceiver

Peak Power - X Band - 75 kw
- S Band - 75 kw

3.2.6 Pulse Lengths

X and S Band
Long Pulse - 1 us nominal
825 pulses per second nominal
Medium Pulse - 1650 pulses per second nominal
Short Pulse - 3300 pulses per second nominal

3.2.7 Receiver Type

Switchable logarithmic.

3.2.8 Dynamic Range

X and S Band 75 dB nominal
Noise Factor - X Band 7 dB maximum
- S Band 4 dB maximum

3.2.9 Operational

Range discrimination better than 15m measured on the .5NM range scale using $10m^2$ relectors at a range of .3NM

Bearing discrimination better than 1.1° and 2.3° for the X and S band respectively measured on the .5NM range scale using $10m^2$ reflectors at a range of .3NM.

Minimum range better than 50M measured on the .25NM range scale using a $10m^2$ reflector and an antenna height of 5m.

Bearing accuracy better than 1°

Heading marker accuracy better than .5°

3.2.10 Processing Options

Anti clutter STC, X and S Band

Depth - 60 dB nominal, 45 dB minimum
- 70 dB maximum

Range - 60 us nominal, variable by means of a preset control over range 30 us to 80 us.

Algorithm $\frac{1}{(\text{range})}$ where n = 3 nominally

3.3 Interface Definition

3.3.1 External Display Interfaces

The display shall have external input interfaces to microwave radar, H.F. radar, television, computer and a high speed digital output interface for video.

The microwave radar interface shall use signals shown in Table 3.2.

SIGNAL	VOLTS	CHARACTERISTICS	PULSE WIDTH
Trigger 1 (A Scan)	TTL	0 to 5 KHz	100 ns min.
Trigger 2 (PPI, B Scan)	TTL	0 to 5 KHz	100 ns min.
Azimuth Clock Pulses	TTL	4,096 Hz	100 ns min.
Azimuth Reference Pulse	TTL	0 to 1 Hz	100 ns min.
Video PPI	0-2V	30 MHz	
Video A Scan	0-2V	30 MHz	

Table 3.2
Radar Interface Signals

The H.F. Radar interface shall use processed HF radar data for direct video presentation. This data will be accepted in a format suitable for a television interface.

The display shall be capable of accepting television video for line rates of 525, 625, and 875. Interface of 2:1 and 50 and 60 HZ field rates shall be accommodated.

The IHD/CAS shall interface with the external computer over a 16 bit parallel interface.

The display shall interface with digital video information over a 20M bit/second input channel. The protocol over this channel shall be such as to allow the transmitting sensor to set up the basic parameters of the scan, such as, scan direction, (up, down, left, right) line length, and starting position in the video area. Once this has been set up, pixel data may be sent continuously and the display formatting electronics shall automatically write the data into the correct locations.

3.3.2 Electric Power Interface

The display shall use 115 volts, 60 HZ, single phase.

The sensor shall use the following power requirements:

Microwave Radar	-	440V 60 Hz 3 Phase
H.F. Radar	-	to be determined
L.L.L.T.V.	-	120v 60Hz
I.R.	-	120v 60Hz

3.3.3 Display Internal Interfaces

The display internal interfaces shall connect the following major items:

Display Driver Assembly to T.V. Monitor (Display Console)

Display Driver Assembly to Operator Contol Unit (OCU)

The display user is required to generate software for each application of the display. This software will execute in the display processor. To simplify the user software, display software modules shall be provided which perform basic functions for scheduling and interfacing between user software, the display driver assembly and the sensor processors.

The display processor shall include provision for the sounding of an audible alarm under user software control.

Control of the display and selection of its functions shall be performed by the display processor using the commands defined for the display driver software. These commands fall into four categories:

O.C.U. and T.V. Monitor
Video Processing and Display Functions
Graphics/Track Management Functions
Status/Test Functions

3.3.4 Display Processor

The display driver assembly shall interface with a computer, designated the Display Processor. The computer shall perform display processing applications functions, under user generated software control.

All sensors shall incorporate the most effective signal processing techniques for the particular sensor in question.

Standard rain and sea clutter processing features such as FTC and STC shall be implemented. Constant false alarm rate (CFAR) capability shall be considered. CFAR techniques do not necessarily improve signal to clutter ratios, but ensure that the best signal to clutter ratio is available. Therefore, all techniques that improve the signal to clutter should be considered. At present the Japan Radio Corporation Sea Ice Radar offers true signal to clutter ratio enhancement and utilizes scan to scan correlation to accomplish this. Techniques utilized by McGill University shall be investigated and incorporated if they prove superior to the J.R.C. system. In principle, any number of images may be averaged, but care must be taken to ensure that targets have not moved too far in the time interval from the first to the last image. Unless the target is stationary, averaging over longer time periods will probably degrade target size, shape and intensity proportional to the time period itself and the speed of the target. Long term averaging, will in fact, eliminate moving targets such as ice.

3.4 Functional Characteristics

The colour monitor shall be a medium resolution device.

The Operator Control Unit (O.C.U.) will consist of a control panel connected to a chassis. The purpose of the O.C.U. is to allow system control.

A trackball shall be provided, of a size between 2" and 3".

A 3" square touch panel shall be provided off-screen.

A standard keyboard shall be provided. The ASCII code associated with each character or control function is transmitted to the Display Processor on selection.

A total of 7 momentary contact Q.E.B.'s shall be provided. These buttons shall be used for standard functions and three shall have unassigned functions. Each Q.E.B. shall contain a lamp which shall be activated by the Display Processor. The three lamp states are:

On
Off
Blink

There shall be an indicator lamp marked BITE FAIL. This will be driven by an automatic fault monitor attached to the Console Controller in the O.C.U.

There shall be a lighted pushbutton marked BITE, which when pressed, will initiate the BITE routine. The lamp will be lit while the routine is in progress and will extinguish upon completion. A fault detected by BITE will cause a lamp marked BITE FAIL to be latched on. The BITE process shall be initiated by the Display Processor on recognition of the button press.

Five rotary controls shall be provided to perform the following functions:

Graphic brightness
Video brightness
Trackball cursor brightness
Radar threshold
Audio Alarm Volume

A lighted pushbutton switch shall be provided to switch power to the electronics units.

3.5 Video Processing & Display Functional Characteristics

3.5.1 Display Format

The IHD/CAS shall have two separate memories. Sensor video information shall use a video memory of 512 x 512 picture cells (pixels) with each pixel having 4 bits for intensity. Sensor video colour shall not be dynamically selectable. Characters and graphics shall use a graphics memory covering the full extent of the 625-line raster (585 lines at 761 pixels/line) with each pixel providing a colour shade (of single intensity) defined by 4-bits, ie. 1-bit for each of the three primary colours and one bit for BLINK. The video area shall be controlled in size (up to a maximum of 512 x 512) and position within the complete raster by the Display Processor.

3.5.2 Radar Processing and Display

The digitizer shall accept radar trigger, radar video and binary azimuth information. The radar video shall be digitized to a resolution of 8 bits giving 256 levels of signal intensity. The sample rate shall be great enough to prevent aliasing when digitizing data with a 50 ns pulse width.

Number of signal sources - 4 independent (or commonly triggered with any combination.

Maximum Aplitude - 5V

Maximum Offset Range $\pm$ 1V

Nominal Impedance	- 75 ohm (connected to video buffers)
	- 50 ohm (connected to A/D converter)
Type of Characteristic	- logarithmic
Max. Bandwidth Frequency	- 20 MHz
	- 3300 (on 50 nanosecond pulse width)
PRF	- 1650 Hz (on 1 u sec. pulse width)
	- 825 Hz (on .25 u sec pulse width)
PRF Amplitude	- + 25V (+ 30% internal regulation
Antenna Synchro Rotation	- 3 wire synchro resolver information
Reference Frequency	- 400 Hz + 5%

Analog to Digital Conversion

Resolution	- 8 bits
Signal/Noise Dynamic Range	56 dB
Maximum conversion rate	- 20 MHz
Linearity	- 1/2 least significant bit

A radar video threshold control shall be supplied on the O.C.U., that shall control the offset value of the video input to the A/D converter.

In the P.P.I. mode the selected radar shall be displayed in the video area. The offset and scale of the radar shall be provided by the Display Processor in external units (data miles), relative to the Display Reference Coordinate.

a) Range Scales: Range scales in binary increments from .5 data miles to 256 data miles (ie. maximum coverage shall be 128 data miles).

b) Offset: The P.P.I. display shall be capable of being offset anywhere within the 256 mile square coverage. Offsets of 1.5 times selected range scale shall be permitted without spoking of the video.

c) A P.P.I. display displaying analog radar video shall complement the digital display.

CRT type - solid state
CRT diameter - 12" or 16"
Phosphor type - P26

A bearing data transmission system shall utilize synchro inputs.

Range scales shall cover the following ranges.

	Range Scale	Range Rings	Long Pulse	Short Pulse
Minimum	.25 nm	.05 nm	-	.05 us
Maximum	96 nm	16 nm	1 us	-

Video Bandwidth 16 MHz

3.5.3 Framing Sensor Processing and Display

The IHD/CAS shall interface with Framing T.V. tape video, with lines per frame selected as 525, 625, and 875. The IHD/CAS logic shall perform A/D conversion and store the T.V. video information in the video memory, thus permitting annotation, external image processing by the Display Processor.

The color imaging system shall have the following features.

The system shall have a 512 x 512 dot resolution by 4 bit plane colour graphics board. An on board colour encoder shall provide up to 16 colours in American (NTSC) standard. This will enable the system to drive standard low cost colour monitors on a single 75 ohm cable. An on-board phase locked loops shall allow the video outputs to be synchronized to an external video source, in this the LLLTV and 1R system. Input/output registers shall allow the user to read from or write to any addressed display dot, turn video on or off, load any value into entire video display memory, scroll the display and check the status of the board.

Imagery that falls outside the 512 by 512 video area shall not be displayed.

The video shall be digitized to 8 bits. A level-slice table loaded from the Display Processor shall reduce this to 4 bits prior to entry into the video memory. A linear transfer function shall be set into the table as a default condition on power-up.

3.5.4 Line Scan Sensor Display

The IHD/CAS shall provide a High Speed Serial Interface with a maximum input data rate of 20 MHZ and a protocal to accept digitized video and load it directly into the video memory. The protocal shall be such that, for line scan formats, maximum use shall be made of the bandwidth of the digital channel for data transmission.

The color imaging system shall be strappable on the input/output address space of the display driver, and use light consecutive byte locations. The imaging system shall use a simple (X, Y) coordinate addressing scheme.

X specifies the horizontal column and reads left to right, ie. 0 is the left most dot, 511 the right most dot. Y specifies the line and reads top to bottom, ie. 0 is the top line, however the top line can be changed by the scroll register.

Two directly addressable registers store the (X, Y) coordinates of a given dot. The X and Y registers shall be 10 bits each allowing for a 512 by 512 dot resolution. The registers shall be capable of being written to by byte or word instructions. For word instructions both X and Y are loaded at the same time.

After the dot coordinates have been loaded into the X and Y registers the dot colour can be loaded by outputting data to location 0. The colour of the addressed dot can be read by reading from location 0.

3.5.5 Video Memory Scrolling

The video memory shall be scrolled in Y independently of the graphics memory by specifying the Y address of the memory line desired at the top of the raster. This position shall be specified to a resolution of 4 lines.

3.5.6 Scan to Scan Integration

The scan to scan integration techniques which consist of averaging the data at each cartesian pixel over several successive images shall be considered. The number of images shall be variable and determined by the operator.

An equation which could be used is shown here

$$S_{n+1} = S_n + \frac{1}{2^k}(X_{n+1} - S_n)$$

where S_n+1 is the new sample to be stored in video memory

S_n is the old sample from memory

X_{n+1} is the new input sample from the sensor

K is the filter time constant

Much more advanced algorithms under development should be considered.

3.5.7 Target Trails

On selection, target trails shall be implemented by combining video data from a new scan with video data from the previous scan such that

$$S_{n+1} = X_{n+1} \quad \text{if} \quad X_{n+1} > S_n$$

$$\text{else} \quad S_{n+1} = S_n + \frac{1}{2^k}(X_{n+1} - S_n)$$

3.6 Graphics & Target File Management Requirements

3.6.1 General

This IHD/CAS shall be capable of displaying graphics anywhere within the limits of the 625 line T.V. raster at full resolution. The graphics memory shall therefore be a minimum of 585 lines x 761 pixels/line.

A capability to incorporate brightness levels shall be incorporated in the graphics memory shall be 4 bits deep, giving the capability of off, high brightness and blink, for any of the three colours and their combinations.

The blink rate shall be 1 Hz, with on-off ratio 1 : 1

The IHD/CAS shall have the capability of drawing ASCII characters, selected symbolic characters, vectors, arcs and circles in both positive and inverted video format. It shall also allow user defined line tapes and character set. Graphics shall be overlayable without loss of information.

The full 64 character set of displayable ASCII characters shall be implemented. Two character sizes shall be provided as shown in Table 3.3.

Type	Matrix Pixels	Character Size Pixels	Character Size in Inches
Small	6 x 11	4 x 6	.07 x .11
Large	10 x 15	6 x 8	.11 x .15

TABLE 3.3
IHD/CAS MATRICES ASCII

The IHD/CAS shall be capable of drawing vectors and strings of vectors of any length and slope. The vectors shall be defined in two ways; by the end points; or by the start points plus length and slope.

The IHD/CAS shall be capable of drawing arcs of any radius and angular subtense, up to full circles. A full circle may be drawn by making the angular subtense 360 degrees.

The lines constituting the vectors and circles shall be 1 pixel wide. One of two line types shall be selectable. These types are continuous or dashed.

The possible character symbology shown in table 3.5 may be implemented. Two symbol sizes shall be provided as shown in table 3.4.

Type	Symbol Matrix Pixels	Symbol Size Pixels	Symbol Size Inches (19 in T.V.)	Subtense at 18 inches (min. of arc)
Small	9 x 9	8 x 8	.15	29' x 29'
Large	12 x 12	11 x 11	.20	39' x 39'

TABLE 3.4
IHD/CAS MATRICES USER PROGRAMMABLE

3.6.2 Graphics Addressing

Graphics parameters (position, length, etc.) shall be defined in two alternate coordinate systems, pixel coordinates (internal or display units) and data mile (dm) coordinates (external units). In the latter case the graphics position shall be relative to a Display Reference Coordinate (DRC). The position of the display raster shall therefore also be defined in data miles, relative to the DRC.

The smallest piece of graphics that can be identified (line, character, etc.) shall be called an Entity. A graphics Entity may be enabled, moved, suppressed or change intensity, but components of the entity may not be altered independently of other components of that entity.

All displayable graphics data shall be defined in Tag blocks and may be moved, deleted, or altered by reference to the tag block number. A total of 250 tags shall be definable. A maximum of 25 entities may be specified within one tag. The maximum tag length shall be 128 words.

Tags shall be maintained in a Display File. The Display shall be periodically refreshed from this file to eliminate pinholding caused by the movement of intersecting entities. The Display File shall be large enough to accommodate the graphics load in table 3.6, which requires approximately 10 K words.

TABLE 3.5
USER PROGRAMMABLE SYMBOLOGY EXAMPLES

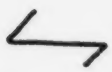
	Ice Edge
	Iceberg
	Hazard (Blinks)
	Reference Point
	Charted wreck
	Helicopter
	Reference Point
	Fix
	Ownship
	Surface Ship
	Ball tab

TABLE 3.6
GRAPHICS LOAD

ITEM		QUANTITY
1	Dynamic tracks	140
2	Static tracks	120
3	Closest point of approach and intercept vectors and symbol.	30
4	General pupose lines	10
5	Relative bearing lines	5
6	Utility circles	5
7	Mapping vectors, average length 64 pixels	136
8	Alphanumeric text characters	150
9	Predicted target motion paths average length 256 pixels.	20

The Display shall be capable of windowing. The Display Processor shall define a rectangular field of view within the full graphics raster within which entities whose base position is defined in data miles shall be windowed. For most applications, this field of view shall be the same as the video overlay area up to the maximum 512 x 512 pixels, although graphics - only applications may define the full raster (761 x 585) as the external - unit field of view. Entities defined in pixels shall be windowed by the raster. Those portions of all entities that fall within the defined window shall be displayed except for characters and symbols, when the entire symbol matrix must lie within the field of view for the symbol to be drawn.

The principle of operation is shown in figure 3.7. It should be noted that the IHD/CAS Function Generator shall only compute addresses within the window. Out of bound addresses shall not be computed in order to minimize the total time taken.

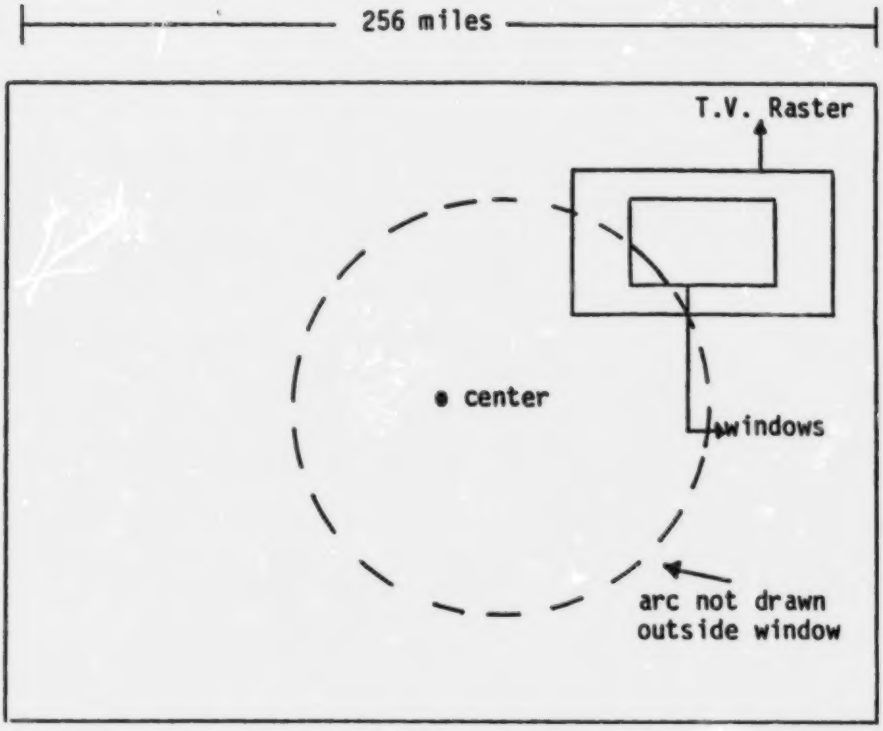


Figure 3.7
WINDOWING

3.6.3 Graphics Magnification

A graphics magnification of two and four times shall be provided.

3.6.4 Cursor

A trackball cursor symbol and cursor control shall be provided.

This cursor shall be contrained to move within the video graphics field of view under Display Processor Control. The cursor shall be positioned either by the trackball or the Display Processor. The cursor shall be selectable from a number of types by the Display Processor as follows:

a) Ball Tab Cursor
b) Horizontal Line Cursor
c) Vertical Line Cursor

The horizontal and vertical line cursors may be enabled independently or together.

3.7 Physical Characteristics

The IHD/CAS shall consist of the following physical units:

Display Drive Unit
Power Supply Unit
TV Monitor
Operator Control Unit
PPI
Display Processor

X Band Radar Antenna Assembly
X Band Power Supply
X Band Transmitter
X Band Receiver
X Band Sync and Signal Junction Box

S Band Radar Antenna Assembly
S Band Power Supply
S Band Transmitter
S Band Receiver
S Band Sync and Signal Junction Box

Ka Band Radar Antenna Assembly
Ka Band Power Supply
Ka Band Transmitter
Ka Band Receiver
Ka Band Sync and Signal Junction Box

} if applicable

HF Radar Antenna Assembly
HF Power Supply
HF Transmitter
HF Receiver
HF Sync and Signal Junction Box

} if applicable

IR Scanner
IR Photo Section
IR Analog Section
IR Digital Section
IR Heavy duty Tripod
IR Remote pan/tilt controller
IR Liquid nitrogen container

LLLTV Scanner
LLLTV Photo Section
LLLTV Analog Section
LLLTV Digital Section
LLLTV Heavy duty tripod
LLLTV Remote pan/tilt controller

The following units shall consist of 19 inch rack mountable modules.

Display Drive Unit
Power Supply Unit for Display Processor
Display Processor
X, S, Ka, HF Band Power Supply
X, S, Ka, HF Band Transmitter
X, S, Ka, HF Band Receiver
X, S, Ka, HF Band Sync and Signal Junction Box
IR, LLLTV Analog Section
IR, LLLTV Digital Section
IR, LLLTV Remote Pan and Tilt Controller

The TV monitor shall be a 24 inch rack mountable set. The TV monitor, PPI and Operator Control Unit shall be located on the bridge or in the vicinity of the bridge.

The TV Monitor, PPI and OCU shall be capable of 100m separation from the Display Drive Unit. All interfaces shall be capable of operating over 100m using TRF-58 cable.

3.8 Reliability

3.8.1 Quantitative Reliability Requirements

The specified MTBF for the IHD/CAS shall not be less than 500 hours when operated under the environmental conditions specified.

The contractor shall implement an effective reliability program.

The mean corrective maintenance time (Mct) to repair the IHD/CAS shall not be greater than 45 minutes. The maximum corrective maintenance time shall be less than 2 hours at the 90th percentile.

3.8.2 Preventive Maintenance

Preventive maintenance of the IHD/CAS shall be limited to TV and PPI monitor adjustments, the replacement of air filters and lubrication of rotating sensor equipment.

All modules of the IHD/CAS shall be accessible.

Repair policy

1st line: On board servicing by ships personnel limited to replacement of modules and components available from ships spare kits.

2nd line: On board servicing by shore based personnel, principally by module replacement, but a limited amount of servicing to component level.

3rd line: Repair of units and modules down to component level in a shore based workshop.

4th line: Major overhauls of capital units by manufacturer.

3.8.3 Environmental Conditions

As specified in the preliminary specification for the IHD/CAS, the system sensors and external components will be capable of withstanding the extremes of the arctic climate.

The internal components of the IHD/CAS shall conform to the operating temperature conditions of range 4 of MIL-E-16400.

The IHD/CAS shall be capable of extended storage within the non-operating range specified in MIL-E-16400 (-62°C to 71°C) when the IHD/CAS is removed from storage to the operating temperature range the equipment shall operate correctly with no mechanical or electrical damage.

3.8.4 Vibration

The IHD/CAS shall be capable of withstanding the type 1 vibration test of MIL-STD-167. Equipment which is rack mounted shall be tested as a complete unit in order to simulate actual shipboard conditions.

3.8.5 Humidity

The IHD/CAS shall be capable of withstanding the humidity requirements as specified in MIL-E-16400.

3.8.6 Transportability

The IHD/CAS equipment shall be capable of sufficient disassembly to allow shipping by commercial and ground carriers. After reassembly no servicing or realignment shall be required for correct operation.

3.9 Quality Assurance

3.9.1 Workmanship

The IHD/CAS will be manufactured in accordance with published workmanship standards of the manufacturer.

3.10 System Testing

3.10.1 Functional Testing

Thorough functional testing of the IHD/CAS will be conducted during the engineering program. This may make use of pre-recorded sensor data collected during the Petro Canada/TDC field trials conducted in 1981.

A test, analyze and fix program will be performed.

3.10.2 Environmental Testing

A formal test plan and report will be conducted.

The following tests will be performed:

(i) Temperature: per Mil-E-16400G (method 501 and 502 of MIL-STD-810) and Mil-STD-781C Test Plan VC. Equipment temperature cycled between -150°C and +55°C once per day.

(ii) Humidity: per MIL-E-16400G (method 507, procedure IV of MIL-STD-810)

(iii) Vibration: per MIL-STD-167, type 1

3.10.3 Acceptance Tests

A test plan will be prepared by the contractor to display compliance with the functional specification.

4. DEVELOPMENT PLANS

4.1 Offshore Development Plans

Generally speaking, in the energy sector, the requirements for ice hazard detection systems have probably increased during the past year even though the tempo of production planning and implementation seemed to be slowing. Until very recently, dropping oil and gas prices, a dearth of Beaufort discoveries and a less than favourable political climate seemed to indicate that oil production facilities requiring first rate ice hazard detection facilities were a long way off, the first not being in place before the 1992 - 1995 time frame.

However a change in government, promising discoveries and new production techniques have combined to provide a breath of fresh air to offshore operators production planners.

For example, planners for Mobil Oil Canada Ltd. have revised their thinking on how the Hibernia oilfield should be developed, and if approved by government, offshore production could start as early as 1988.

A number of operators are involved in the offshore production planning processes, including Dome Petroleum, Gulf Canada and Petro-Canada. Their individual production plans and schedules will be described later, but this new optimism for early production has stimulated the proposals for two phase development plans, the first phase stage including the use of purpose built semisubmersible production platforms with tanker storage and subsea production facilities.

The trend in production system development seems to be toward early field development to provide a quick economic return for the large sums of money needed for further exploration and gravity based production systems.

Therefore a change in thinking on production methods using combined subsea and floating production techniques has begun to take hold. Subsea systems generally bring a field on stream sooner than a fixed platform. This results in earlier cash flow which, when combined with lower capital costs, makes subsea systems economically attractive. However, it is downtime during the life of the field that this economic advantage can be lost.[1] Downtime has two major sources, the first having to do with subsea equipment maintainability. The other source is of concern to us, and this is limitations due to environmental effects. Ice and icebergs may be the greatest threat to floating production systems, and as a result, these systems will add a further justification for systems development of a multi-sensor, sophisticated Ice Hazard Detection/Collision Avoidance System. Figure 4.1 illustrates a subsea production system for arctic offshore areas.

1 Gibb, Peter, Advancement made in Production Risers for Floating Systems. Atlantic Energy News, October 1984.

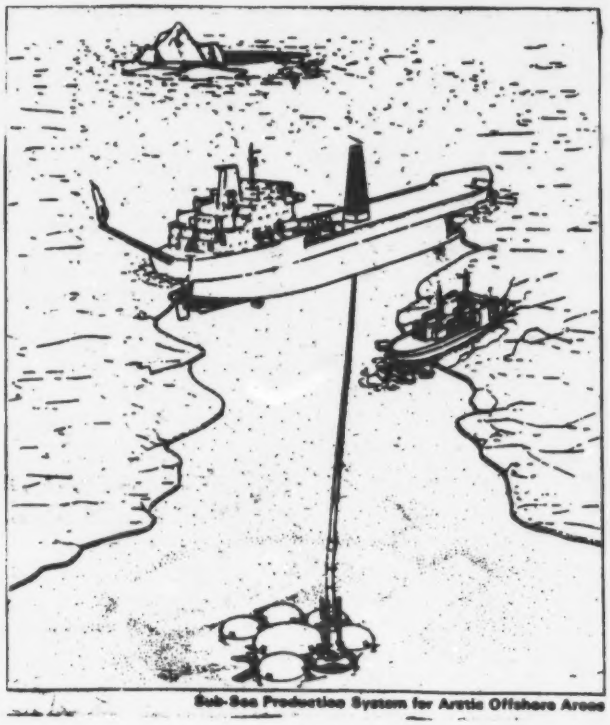


Figure 4.1

Illustration courtesy of Atlantic Energy News.

4.1.1 Gulf Canada Resources Ltd.

To date, industry has drilled 50 wells in the Beaufort Sea, of which 15 are oil discoveries and seven are gas. This activity has proven up more than a billion barrels of oil and three trillion cubic meters of gas reserves.

Gulf and its partners have been giving serious study of the feasibility of small pool development on acreage in water depths of 60 to 90 feet. The major challenge is to develop a cost effective system to transport the oil to southern markets. Although a tanker based system has certain advantages over a pipeline, such as flexibility, Gulf believes the solution is a 20 inch pipeline up the MacKenzie Valley. Presence of permafrost has been a major environmental constraint, but now there is a design tht will not adversely affect the environment, and at the same time allow the line to be buried. This feature has lowered the cost of the pipeline considerably, but to support a line with a capacity to move 150,000 barrels per day, 700 million barrels of recoverable oil is needed. This threshold has probably been reached with Gulf's discoverey at Amauligak where more than 400 million barrels of recoverable reserves are located. Following delineation drilling beginning in the Spring of 1985, Gulf and its partners will likely file a development application during the Summer of 1986 for a three billion dollar pipeline, gathering system and production plant.

4.1.2 Mobil Oil Canada

Mobil is considering a two stage development plan for Hibernia. The first stage involves the use of a purpose built semisubmersible production platform with tanker storage. During this first stage, production is expected to be in the order of 50,000 barrels per day. Mobil would use shuttle tankers to move the oil from the storage vessel to refining facilities. Produced gas in excess of fuel needs would be reinjected into an appropriate reservoir.

The second stage of Hibernia development could involve expansion of the first stage floating system, or installation of a fixed concrete production platform, or perhaps some hybrid structure. During the second stage it is envisioned that Mobil will again transport the oil to refinery facilities by shuttle tankers. The gas may be transported ashore by pipeline or tanker. The expected price for this development is still in the order of between five and eight billion dollars, depending upon the production scheme implemented and economic studies undertaken by the Newfoundland Government overwhelmingly support commercial viability regardless of the production system option selected.

Irregardless of the production scenario, the location of the facility in iceberg alley warrants the development of the best possible Ice Hazard Detection/Collision Avoidance System. It can be foreseen to play an important part in the iceberg management system utilized either aboard gravity based platforms, floating production facilities, whether mobile or immobile, shuttle tankers and service vessels.

Recent work by the Engineering Department of Memorial University has conducted that iceberg motion characteristics of icebergs several thousand tons in heavy seas could produce impacts upon offshore structures equivalent to icebergs upto one million tons in a more static environment. Therefore, iceberg detection systems utilized in the Grand Banks and Labrador areas will not only require long detection ranges for large icebergs, but will also require a significant detection capability for smaller icebergs. The variety of explanation, transportation and production systems that are planned for use in this region continue to make this area one of the most demanding of iceberg detection systems.

This requirement is supported by the extensive work that has been undertaken by the operators and has been reported upon in previous reports.[2]

Hibernia Development Plan:

November 1984	-	Submission by Mobil of EIS will present feasible options.
June 1985	-	Submission by Mobil of Development Plan.
Production	-	1988 - 1992 - total cost 8 billion dollars operating cost 300 - 400 million dollars/year

2 Harvey, M. System Specification for an Ice Hazard Detection/ Collision Avoidance System., Viatec Resource Systems Inc. 1983.

4.1.3 Panarctic Oils/Arctic Pilot Project

In 1974 Panarctic discovered a small oil field on Cameron Island at Bent Horn. At that time, crude oil prices were not high enough to make production from that isolated location economically viable. Panarctic now plans a small pilot project to product about 500,000 barrels per year accumulated in storage tanks over the Winter. It will be shipped out in one convoy during the Summer using the same type of ice strengthened tankers that Panarctic employs in its annual fuel resupply.

The oil fields discovered by Panarctic are very large, and there is already more than sufficient proved reserves at the Cisco oilfield to support an initial production of 50,000 barrels per day using one large icebreaking tanker. Ice conditions are severe and a Class 10 icebreaking tanker would be required. It is expected however that it will be 1990 before any large scale production capability can be put in place. Once in place, however, a fully capable ship borne ice hazard detection/collision avoidance system will need to be in place for safe, efficient and environmentally acceptable transportation.

On the gas side, High Arctic gas reserves total about 18 trillion cubic feet, adding some 25% to Canada's reserves. Unfortunately the Arctic Pilot Project and the Polar Gas Project, to market these reserves, have been put off indefinitely by weak markets in the U.S.A. Polar Gas plans a smaller scale project to take gas from the MacKenzie Delta Beaufort Sea area, with a later extension to the Arctic Islands. This however, does not utilize LNG carriers but rather pipelines to transport the gas. Therefore, the Class 10 LNG tanker no longer serves as justification to push ahead with development of Ice Hazard Detection Systems. It is expected that it will be 1995 before gas is removed from the high Arctic by tanker.

4.1.4 Canarctic Shipping

The Canarctic Shipping Company Limited operates the M.V. Arctic in ice and iceberg infested waters. This Class IV bulk carrier can be considered typical of commercial transportation systems that have a requirement for ice and iceberg management systems. The vessel makes a number of transits through the Arctic each year and the potential increase in speed made good through the ability of better determining the location of ice and icebergs justifies on an economic basis alone the development of improved ice and iceberg detection sytsems.

For this reason, Canarctic is undertaking the development of the conceptual requirements of the Shipboard Ice navigation support system. The ojective of this system is to develop onboard the vessel a level of ice information and intelligence which will facilitate optimal route selection, and allow for monitoring and refinement of the selected track as the vessel proceeds through the ice. To be totally effective, this system must incorporate long-range strategic route planning, medium range tactical support through the ice, and close range ice hazard detection and avoidance.

Canarctic Shipping is of the opinion that efforts should be directed towards proving the feasibility of internally mounted forward scanning sonars. They envisage a sonar that could be used to detect much larger masses of ice protruding below the water surface, thus increasing the reliability of ice hazard detection. To this end, a project is being conducted to determine the optimum processing and enhancement schemes that can be utilized in forward scanning sonars. The results of this project are as yet unknown by the writer, however, Canarctic is confident that the results will be promising and will show the value of sonar systems as an iceberg detection sensor.

If the results are promising, then the inclusion of sonars in an Ice Hazard Detection/Collision Avoidance System should be considered.

4.1.5 Petro-Canada

Petro-Canada's offshore development plans undoubtedly will include the Terra Nova structure where oil was discovered during 1984. This oil field, on Newfoundland's Grand Banks suffers the same iceberg problems as the Hibernia field. Although development is several years beyond that of Hibernia, Petro-Canada has maintained a positive interest in iceberg detection, mainly as a result of their experiences drilling off the Labrador coast. This work is likely to continue in order to improve the iceberg detection capability for both the exploration platforms currently delineating the structure, as well as future production platforms.

4.2 Ice and Iceberg Research

In support of offshore development plans and current transport and energy exploration activities, a number of government organizations, Universities and contractors have conducted Ice and Iceberg Research during 1984. In most cases projects were conducted on a joint basis, usually between contractor and government groups, or between university and government groups, and in some instances between universities and contractors. The universities active in the area of iceberg research are McMaster University, McGill University and Memorial University. The principal federal government groups involved in ice and iceberg research are the Transportation Development Center of Transport Canada (TDC) the Environmental Studies Revolving Fund (ESRF) of Energy Mines and Resources (EMR) the Department of Fisheries and Oceans (DFO) and the Department of Environment (DOE). Private companies heavily involved in the research of marine radar iceberg detection and management include; Canpolar Consultants, Nordco, and Viatec. Other companies such as Interra and MDA are involved with the development of airborne ice and iceberg management systems. Also C-Core and the Battelle Columbus Laboratories are involved with the development of HF radar systems for Canadian iceberg detection applications.

Table 4.1 outlines the known government funded contracts for ice and iceberg research for 1985. As can be seen, most Department of Environment activities centered upon airborne systems and associated image processing. Much of the ice and iceberg investigations funded by the government also are concerned with iceberg motion and structure interaction, not specifically, detection.

Table 4.1 - Federal R&D Contracts Let

The following research and development contracts have been let with respect to Ice and Iceberg Management during 1984.

CONTRACTOR	SPONSOR	TITLE	AMOUNT
SPAR Areospace	DOE	Radar Sat spacecraft systems definition and critical technology development.	484,275
University of Ottawa	DOE	Expert systems for remote sensing.	57,850
Nordco Ltd.	DND	Refurbishment and maintenance of LORAN-A system situated at Cape Bonavista, Newfoundland.	56,081
Canarctic Shipping Ltd.	DOT	Dedicated field tests ship/ice interaction. M.V. Arctic - logistics and on ice operations - phase IV	207,539
German & Milne Incorporated Ottawa	DOT	Dedicated field tests ship/ice interaction. M.V. Arctic - phase IV (B).	
Arctec Canada Limited	DOT	Studies in connection with updating the Arctic Shipping pollution prevention regulations, group IV-further development of ship (ice collision probability model ASPEN).	62,898
ICE Engineering Ltd.	DFO	Complete iceberg surveys and measurements.	29,550
McMaster University	DFO	Ice radar analysis	75,806
Memorial University of Nfld. C-Core	DFO	Conduct a research program directed to the remote sensing of cold oceans.	200,000

CONTRACTOR	SPONSOR	TITLE	AMOUNT
Philip A Lapp Ltd. - Ottawa, Canada	DFO	Perform and report on a requirement analysis for communication system for the Ice Centre of Environment Canada.	28,992
DIPIX Systems Ltd. - Ottawa, Ontario	DFO	Provide, install and test a prototype ice data image analysis system.	314,140
McMaster University	DFO	Continued analysis of ice radar data.	22,688
Scientific Consulting Services Inc.		Acqusition and implementation of an interactive multi dimensional classification program and specifications for an expert system for remotely sensed data.	48,090
Dipix Systems Ltd.	EMR	Development of an integrated image analysis and digital mapping system.	465,662
Fenco Nfld.	DOE	Evaluation of the AES iceberg drift model.	29,940
Interra Environmental Consultants	DOE	Conceptual and general design of an ice data integration system.	30,000
MacDonald, Detwiler and Associates Ltd.	DOE	Conceptual and general design of an ice data integration system.	29,889

The principal groups involved with surface based sensor research and systems development are:

a) McMaster/Department of Fisheries and Oceans - ice and iceberg image processing, development of coherent marine radar.

b) Memorial University/C-Core/Nordco/Viatec/Department of National Defense/Department of Fisheries and Oceans - HF radar specification, systems development, modelling and field trials.

c) Viatec Resource Systems/Environmental Studies Revolving Fund (Energy Mines and Resources)/McGill University - Marine radar data collection and analysis, IHD/CAS system development, microwave radar modelling.

The activities of these three main groups are detailed in the following sections.

4.2.1 McMaster University/Department of Fisheries and Oceans

Presently research in radar data processing at the Communications Research Laboratory (CRL) of McMaster University has reached the level at which a hardware prototype processor could be built. This processor would incorporate in hardware and firmware many of the image processing techniques proven at CRL using collected data and software implementations of these techniques.

The emphasis of the McMaster research program has been directed towards the mapping and classification of a continuous ice cover. This research has application in arctic waters where ice cover consisting of first-year, multi-year and pressure ridges hamper safe and efficient shipping. Most of the processing techniques developed are applicable to this image-type data. The techniques presently available include:

a) Range Normalization - this feature is implemented using Honomorphic Filtering which enables the range dependence of the radar data to be characterized and removed.

b) Noise Smoothing - a variable size median filter may be used with the data to remove spurious noise.

c) Shadow Enhancement - a great deal of information is contained in the edges within an image. A two-dimensional high-pass filter may be used to extract the high frequency content of the image and an algorithim used to delineate specific types of edges within the data. This resultant information may be incorporated back into the original image to enhance special features of interes (ie. ice edges and radar shadows).

d) Histogram Modification and Colour - by modification of the data to yield histograms distribution, favourable to the human eye, large increase in image interpretability can be obtained. This is also true with effective colour encoding of the data.

Each of these techniques while being useful for radar images of continuous ice cover and other terrain like data are not applicable to the detection of icebergs in open water. The range normalization may be useful in sea clutter limited detection however, there have been no trails with this type of data. Problems still be be addressed by the McMaster group include the choice of:

a) B-scan versus X-Y (Scan converted) architecture for the processing unit.
b) Display resolution required for optimum operator performance.
c) Scan conversion algorithim to be used,

and development of techniques for treatment of the point target detection problem (ie. icebergs in open water).

4.2.2 Memorial University/C-Core/Nordco/Viatec/Department of National Defense/Department of Fisheries and Oceans.

The development of an HF radar for use in detection of ice hazards has progressed to the system specification stage. The Electromagnetics Group in the Faculty of Engineering at Memorial University has developed comprehensive models for propagation and scatter from icebergs in a rough sea at HF (1-30 MHz) Frequencies. These models may be used to define radar system parameters for particular design icebergs and sea states.

Two experiments have been completed to date in an attempt to verify the developed models. These experiments conducted by C-Core with support from the Electromagnetics Group have resulted in two data sets with ground truthed icebergs. The data sets were collected using C-Core's HF ground wave radar operating at 25.4 MHz.

Preliminary analysis of both of these data sets has demonstrated that icebergs can be detected by HF radar. Further data analysis is continuing with personnel from Memorial University, Viatec Resource Systems and C-Core comprising the analysis group. The main areas of analysis and research include:

a) the use of the collected data to implement and test various direction funding routines for use in multi-element monostatic HF radar applications;

b) the estimation of iceberg radar cross sections from the collected data for comparison with the model results;

c) the development of signal processing schemes for the improvement of signal to clutter and signal to noise ratios;

d) the adaptation of the developed models to include multi-static HF radar systems;

e) the engineering specification of radar systems for use offshore and onshore for the detection of icebergs including bergy bits and growlers.

4.2.3 Viatec Resource Systems/Environmental Studies Revolving Fund (EMR)/McGill University

The Environmental Studies Revolving Fund, an energy industry funded federal government administered fund, contracted Viatec Resource Systems with McGill as a sub-contractor to conduct an assessment of marine radars for iceberg detection.

In the winter of 1984 a comprehensive field program was undertaken to assess the iceberg detection capability of existing marine-type radar. The Sedco 706 drilling platform was selected for the trials. The Sedco 706 has four radar systems onboard, two X band (3 cm) and two S band (10 cm), all manufactured by Racal-Decca of Britain. One pair of the X and S band systems comprise the Racal-Decca FI 2459 combined (S/X) system which, until now, has been sold mainly into military applications. This combined system uses antennas which are co-located and synchronized. The complete system with X and S band Transmitter/ Receiver units is mounted on the derrick top at height of 75 meters. In addition, this system is also equipped with low noise receivers for increased sensitivity. The other X and S band systems are standard units with respective antenna heights of 40 and 35 meters.

During the data collection program, recordings of radar video signals were made for various icebergs, ships and oil rigs. These data were collected on an opportunity basis, as for the most part the Sedco 706 is a stationary platform. Iceberg data were obtained for various sea and meteorological conditions. The stability of the platform permitted the collection of data without the usual pitch and roll effects contained in previous data sets such as the Remotec data. The presence of other oil rigs in the vicinity provided stable reference targets for use in the assessment of environmental parameters on radar performance.

The raw radar video signals from each radar were digitized sequentially and stored on standard nine track computer tape. The video was digitized at two different sampling rates with a six bit quantization. In addition, reference recordings were made on floppy disks of fixed targets with a high speed digital oscilloscope.

The data collected has proven useful in identifying critical environmental effects, such as ducting and subrefractions, as well as providing valuable information on sea clutter. The calibration of the radar system has permitted the calculation of iceberg radar cross sections and a normalized radar cross section for the ocean in a wide range of sea conditions. These findings were then compared with a radar model which plots signal to noise ratio as a function of range.

A further study was undertaken to investigate various iceberg enhancement techniques. In-house efforts center around HF radar, cited earlier, and development of an improved analog to digital converter.

5. RECOMMENDATIONS

5.1 Conclusions

5.1.1 Signal Processing

The Remotec data that was collected by Petro-Canada and the Transportation Development Centre has shown itself to be a worthwhile data base for conducting various levels of signal processing. Although quantitative measurements are difficult, qualitative improvements in signal strength can be demonstrated. This is particularly true utilizing scan to scan averaging methods.

A number of image processing techniques were implemented during this project. These included scan to scan averaging, statistical processing, and dynamic threshold processing. Scan to scan integration has shown that a great improvement in target detectability is possible depending upon the meghod utilized and the number of scans averaged. Although scan to scan averaging works, the exponential weighting averaging scheme should not be used.

Although we were only able to average a maximum of 6 iceberg targets, it is recommended that about 32 targets be averaged to obtain the maximum benefit. Dynamic threshold processing is also worthwhile and in the classification of icebergs. This is a most useful method to reduce noise, although it has not been developed to the point where clutter has been significantly reduced. As a detection tool, dynamic threshold processing should be implemented as one of the last processing steps to ensure that the smaller targets are not thresholded out of the display.

Utilizing decision making theory, the results of digitizing a large number of data points and subsequent comparison to a number of generated random numbers enables one to compare the results in terms of critical success index, probability of detection and false alarm rate as a function of the target signal strength above the mode of clutter for different amounts of integration. Curves can be generated which show that for a given target signal strength, the number of samples which must be average to give various critical success indexes. For a modest 2 dB signal, for example, a critical success index of as high as .99 can be achieved if 32 samples are averaged. This would be totally undetectable in a conventional system. In general, a drastic increase in target detectability as a number of samples is increased can be demonstrated.

5.1.2 System Specification

The system specification has been completed to the extent that no more work should be done this until the results of trials with new types of radar have been completed and shown successful, inluding KA band, HF,

microwave type radars. In addition, future efforts in signal processing may provide more capability which can be incorporated into the specification. The real time capabilities of such a system can not be over emphasized. To date, not enough effort has been expended on enabling the systems to operate in real time environment. In order to incorporate the image processing techniques, in an operational scenario, much more work must be done to increase the operating speed, analog to digital conversion process, and the scan conversion process. Once this work has been completed, further changes will be included in the system specification.

5.1.3 Development Plans and Research Activities

Due to a change in priorities some offshore production plans have been deferred and other cancelled. At present, the first of offshore production facility envisioned is Hibernia, being operated by Mobil Oil Canada. This will probably be the first installation requiring a sophisticated ice hazard detection/collision avoidance system. This is borne out of the fact that Mobil Oil Canada is now investigating different air and vessel traffic management systems which will also have the capability of controlling a number of ships and aircraft, some of which will have ice management responsibilities. Other activities in the Arctic such as Gulf Canada's recent discoveries will require extensive resources to develop. Here again, the requirement of large scale ice management systems will be required for a ice and iceberg identification, tracking and avoidance.

On the other hand, some projects have been deferred or cancelled. The Arctic Pilot Project for example, which was one of the early projects inspiring work to be conducted on the field of ice hazard detection system and is not likely to come into existance until mid 1990's. While the emphasis is no longer with this type of transportation system, ultimately, it is believed that this system will proceed. Therefore, we have an opportunity to capitalize on the time available by pursuing an orderly development program. This is an opportunity which should not be lost.

With the inevitable increase in offshore production activities, in Canada's frontier lands, requirements for ship borne ice hazard detection/collision avoidance systems will be increased. This will include systems installed aboard Government icebreaking vessels, research vessels, support vessels operated by shipping companies and the oil companies themselves for oil and supply movement.

Canadian research activities are presently centered around three groups, each containing a government sponsor, a University, and one or more private contractors or consultants. HF radar research is to be conducted by a DND/Memorial/Nordco/Viatec group. Display and processing work is underway with Transport Canada/McGill/Viatec. DFO/McMaster (CRL) are involved with image processing and development of improved sensors. Additionally, Petro-Canada, Mobil Oil Canada and Husky Oil are conducting HF radar research and site specific studies with ESRF and

private contractors to solve site specific and general iceberg detection problems.

5.2 Recommendations:

Our efforts, and those of the Communications Research Laboratory, and the McGill Radar Weather Observatory have shown that digital signal processing can significantly improve the detectability of icebergs and the ability to detect and differentiate sea ice.

What is required are further efforts to design and test real time systems that incorporate the processing options described and enable a user to practically utilize the techniques. Design should commence in particular for a 32 image averaging system that can operate in near real time. The impact on the memory requirements in the computer in particular should be studied. Real time scan conversion algorithms need to be developed. The question of proper sampling rates and resolution have yet to be addressed. Once the problem of real time operation has been addressed, efforts must be concentrated upon incorporating the data from a variety of sensors to a system display. The problems of interfacing the information of marine radar, line scan sensors and various airborne sensors will be challenging but necessary to solve if a true IHD/CAS system is to evolve.

Furthermore, design and development of new improved sensors needs to continue. For example, the development of HF radar specifications needs to continue, based on the analysis of HF radar data sets held at Memorial University. HF radar development as both an iceberg management tool and a traffic management system needs support. Also, coherent marine radar development and assessment of Ka and Ku radars for ice differentiation should continue.

Assuming real time operation, sensor integration and display, and multi sensor mosaicing is successfully undertaken, the integration of iceberg management tools with iceberg management techniques, vessel traffic management schemes and navigation systems is required if IHD/CAS is to be fully accepted.

Finally, application of artificial intelligence can then be applied. For example, the use of discriminant decision function to improve image intelligibility and target detection capability can then be applied. Clearly, much more effort is required.

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APPENDIX "A"

Remotec Data Analysis:

Several computer programs were written to assist in the data reduction. The first phase of the analysis consisted of target selection. Once the desired target was located, all the antenna scans on a particular radar were transferred to a computer disk for easy future access. This usually entailed storing six 45 degree sectors of data representing six consecutive antenna rotations. Using the azimuth information with each record these six sectors were precisely overlayed and averaged to produce one averaged sector. This sector was then used with a thresholding type program and a high resolution monitor to identify and quantify the peak digital value for each target. This digital value was converted to a voltage using Figure A1-1 and then to a power value using the idealized calibration curve of Figure A1-2 and A1-3. Due to the absence of reliable receiver characteristics data with Remotec radars, a realistic, smoothed characteristic is presumed accurate enough to let us continue with the analysis. This characteristic is taken from Decca X and S band radar presently mounted aboard the Sedco 706. While not accurate, its use will demonstrate a workable methodology that will permit a reliable analysis of future data if the opportunity exists to collect it and properly measure the power input.

The results of the measurements taken from the worksheets shown in Appendix "A" to Appendix "1" are tabulated in Table A1-1.

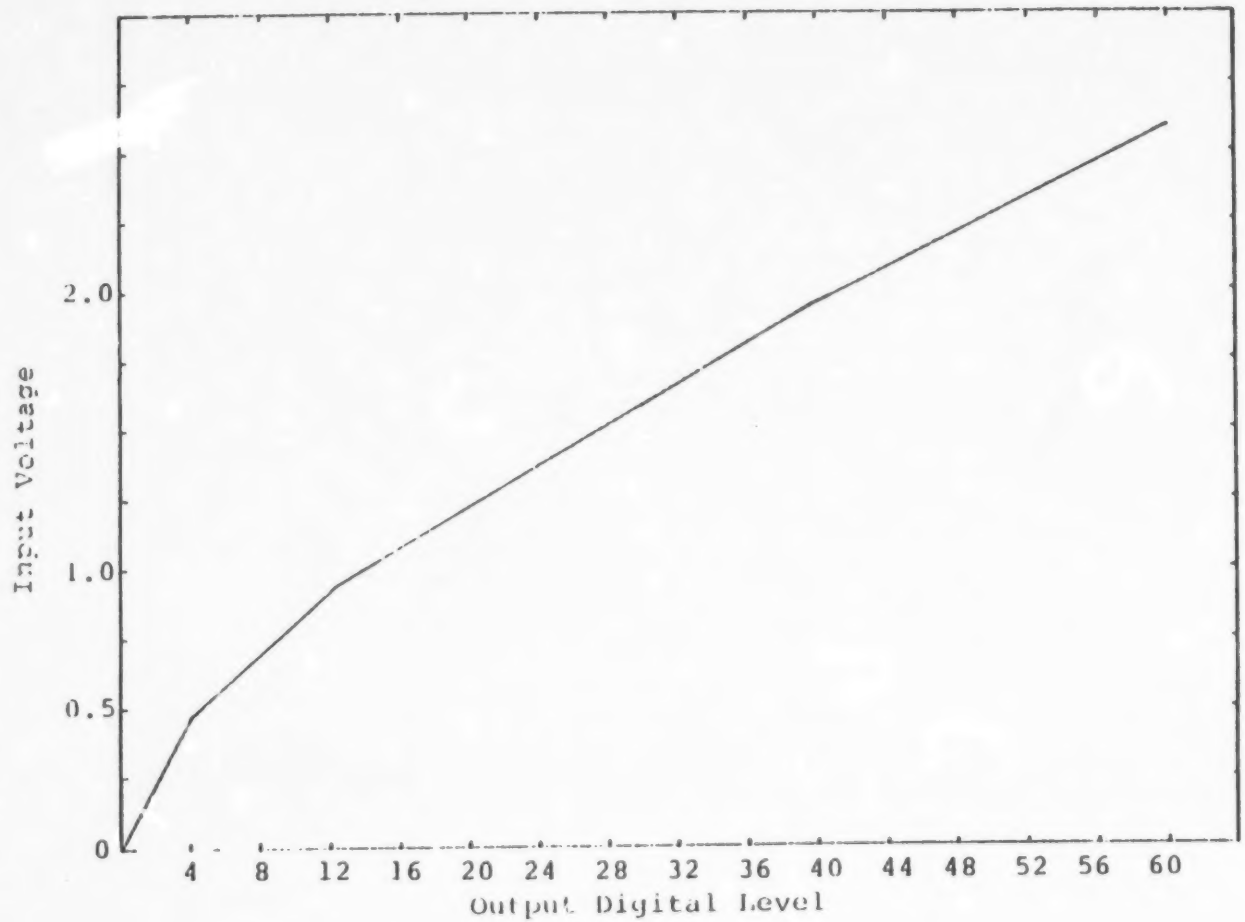


Figure A1-1 Radar Interface Calibration

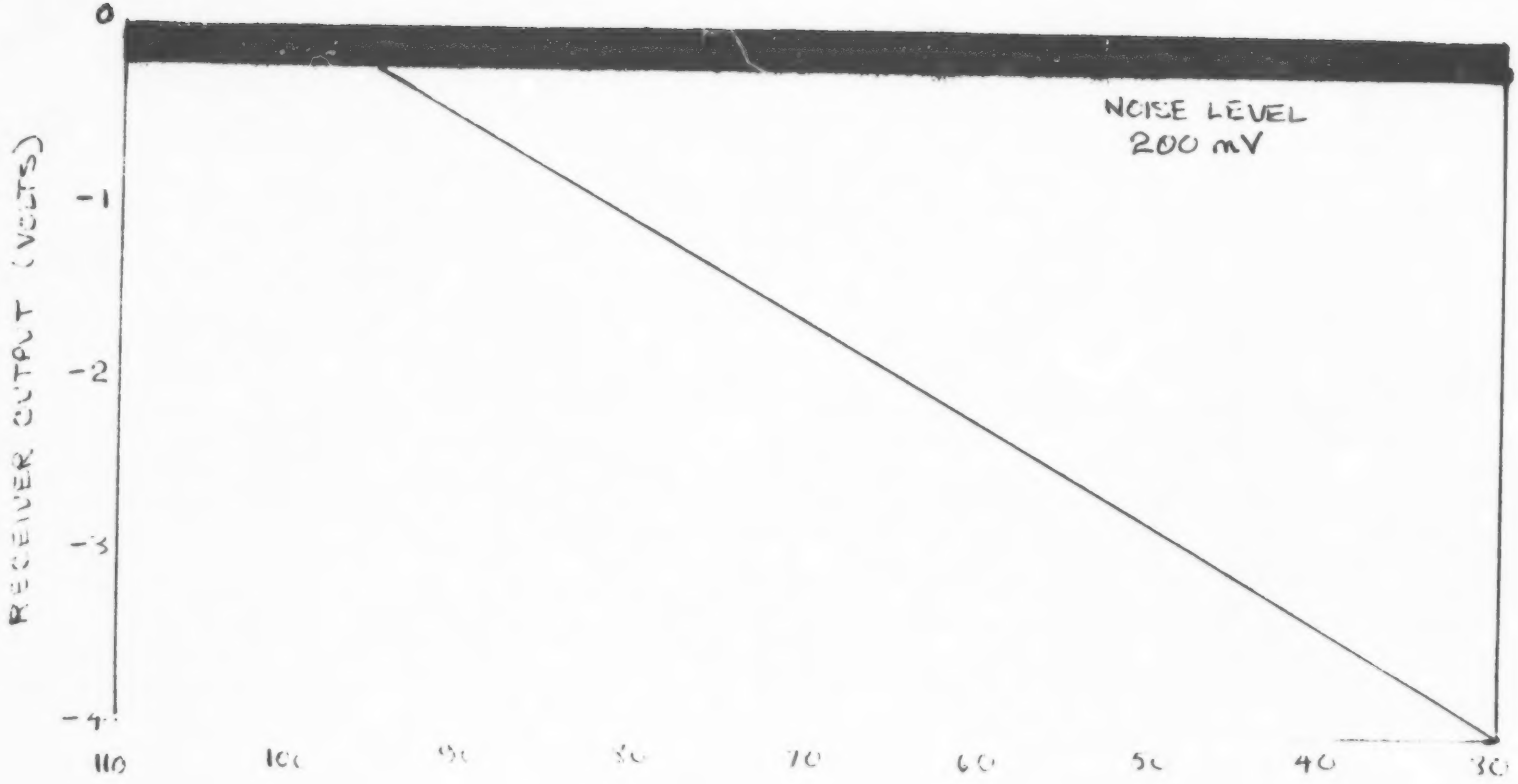


Figure A1-1 RECEIVER CHARACTERISTIC - X BAND RADAR
(TDFA-121 D)

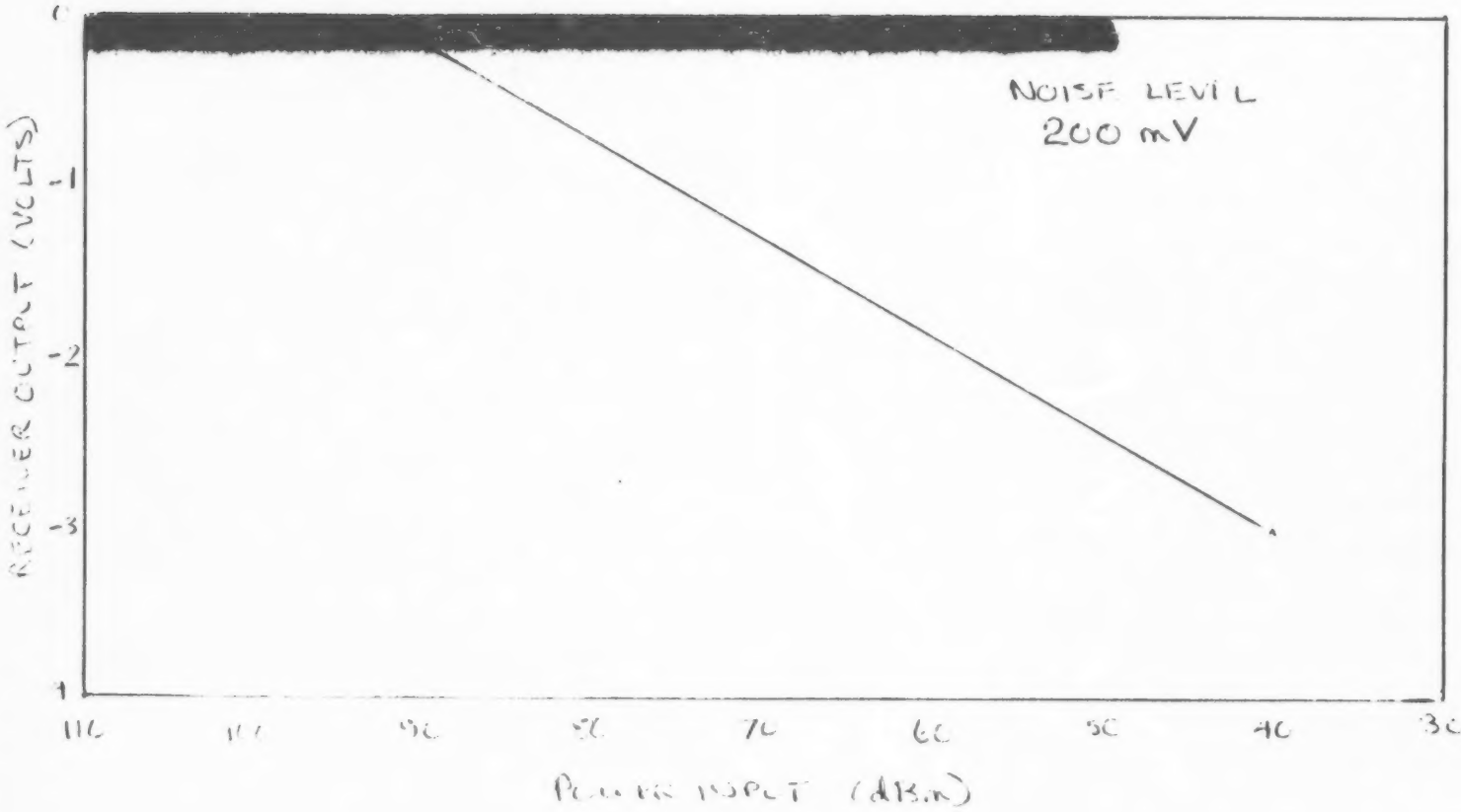


Figure A-3 RECEIVER CHARACTERISTIC - 75 BAUD RADAR (IDEALIZED)

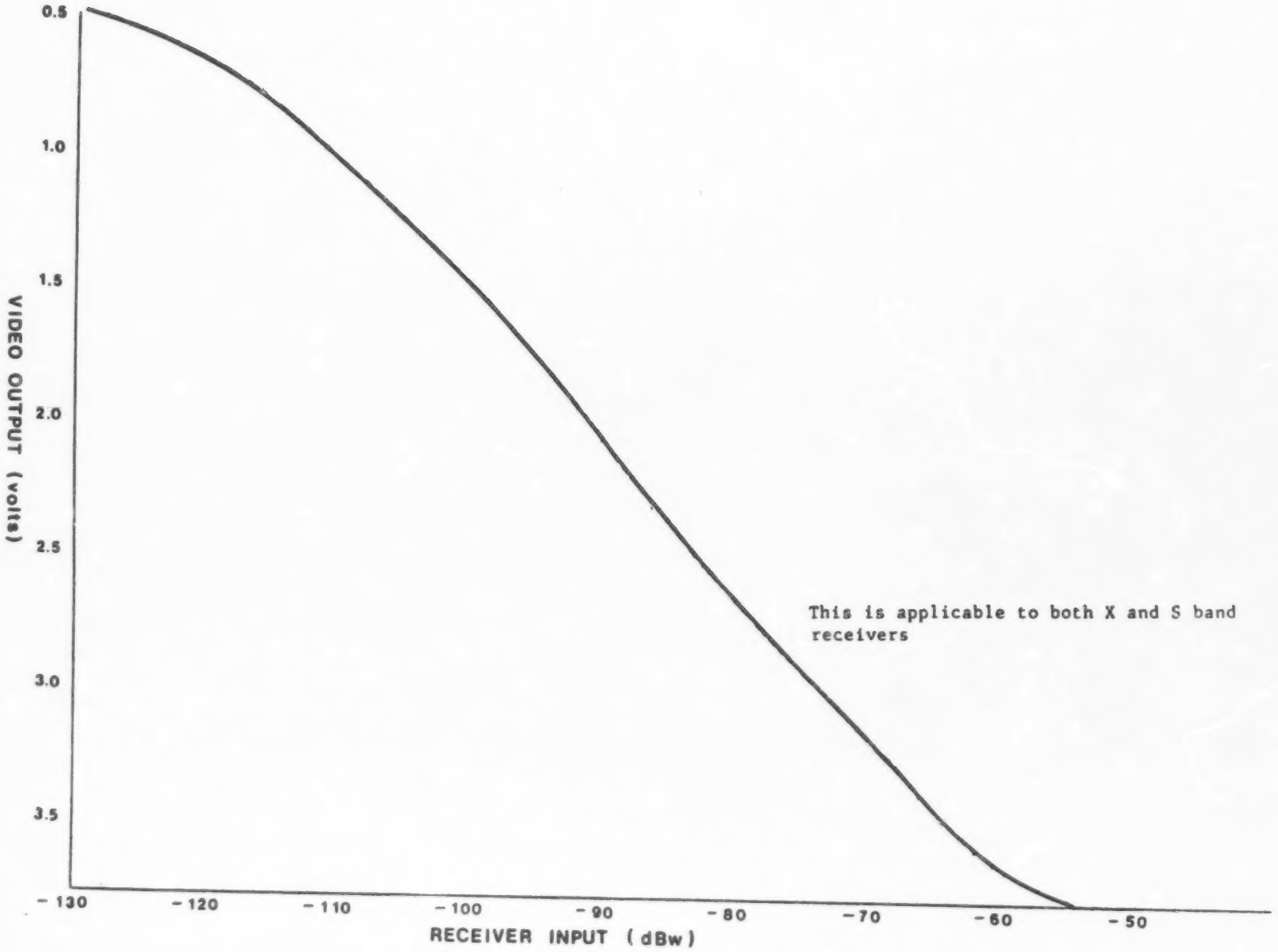


Figure A1-4- RECEIVER RESPONSE CURVE AS MEASURED IN THE LABORATORY USING SIGNAL GENERATORS BY Remotec Applications Ltd

TABLE A1-1 ICEBERG DATA

Iceberg	Event	Range (NM)	Signal Value		Input Voltage		Power Received Idealized Characteristic		Power Received Remotec Characteristic	
			X	S	X	S	X	S	X	S
R01	AG06	9.6	47	-	2.2	-	61	-	59	-
R05	AG06	9.6	52	53	2.3	2.35	59	52	57	59
R06	AD10	6.28	49	56	2.25	2.5	60	50	58	52
R09	AD10	8.5	45	51	2.10	2.3	63	53	61	57
R10	AD10	11.5	59	47	2.55	2.2	54	55	52	59
R10	C003	7.0	63	49	2.60	2.25	53	54	51	59
R14	C003	8.5	63	46	2.60	2.15	53	55	51	59
R15	BM01	7.2	63	60	2.60	2.55	53	49	51	52

General Observations:

The ideal characteristics, while not exact, enables one to make qualitative conclusions about the radars. In fact, the X band ideal characteristic agrees closely with the Remotec characteristic. However S band results do not compare favourably, nor do they appear realistic for the Remotec calculations. It is hard to imagine 3 different Remotec radars, produced by different manufacturers and having different specifications, all having exactly the same receiver characteristic. This type of information makes it difficult to effectively analyze the Remotec data. However, it appears that one conclusion can be drawn utilizing Viatec receiver characteristics. That is that the S1 radar outperformed all other radar for iceberg detection.

The data analysis could have been much more comprehensive had proper ground truthing been available. This indicates a need for more vessel acquired data to determine marine radar performance aboard mobile vessels.

TAPE 2
1

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	AG 06	8 Aug 80	11.30	2	2	6	709

Target	Range	Bearing
VERY LARGE CR. BRG R01	9.6	033

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R35/R36

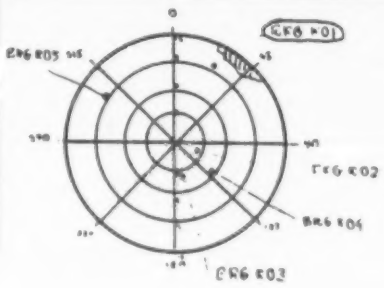
BRG R01	9.6	033
BRG R02	2.9	110
BRG R03	3.4	168
BRG R04	5.2	131
BRG R05	9.6	296

Ring	nM	km	
(1)	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

BRG R01

SHIP	Latitude	74°.42' W
	Longitude	79° 21' W
	Heading	083
	Speed	1.2 kTs
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	2 kTs
	Wind Direction	263
	Precipitation	0
	Barometer	1018.6
	Cloud Cover	1/8
	Visibility	6 nM

RADAR	X1	S1
Cursor	020	
Sector Display	000 — 050	
# Scans Avg.	5	5
Signal Value	47	Not good now
Noise Value	31	



TAPE 2
2

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	AG 06	8 Aug 80	11.30	2	2	6	909

Target	Range	Bearing
BRG R02	2.7	110

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R HSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

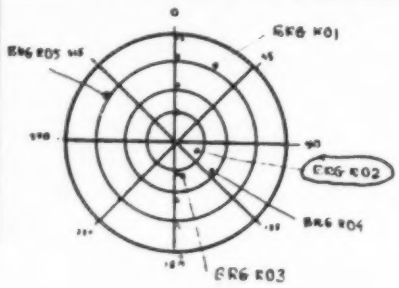
TAPE R35/R36

BRG R01	2.6	083
BRG R02	2.9	110
BRG R03	3.4	168
BRG R04	5.2	181
BRG R05	2.6	296

Ring	nM	km	
①	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74°.42' W
	Longitude	79°21' W
	Heading	083
	Speed	1.2 kTs
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	2 kTs
	Wind Direction	263
	Precipitation	0
	Barometer	1018.6
	Cloud Cover	1/8
	Visibility	6 nM

RADAR	X1	S1
Cursor	100	
Secor Display	090 — 130	
# Scans Avg.	6	6
Signal Value	63	48
Noise Value	26	32



REMOTEC DATA DIGITIZATION

TAPE 2
3

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 80	AG 06	8 Aug 80	11.30	2	2	6	709

Target	Range	Bearing
BRG R03	3.4	168

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

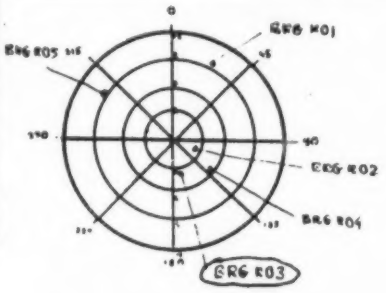
TAPE R35/R36

BRG R01	2.6	023
BRG R02	2.9	110
BRG R03	3.4	168
BRG R04	5.2	131
BRG R05	2.6	296

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	HP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

S H I P	Latitude	74°.42' N
	Longitude	79° 21' W
	Heading	083
	Speed	1.2 kTs
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	2 kTs
	Wind Direction	263
	Precipitation	0
	Barometer	1018.6
	Cloud Cover	1/8
	Visibility	6 nM

RADAR	X1	S1
Cursor	160	
Secor Display	140 — 180	
# Scans Avg.	5	5
Signal Value	N.V.	N.V.
Noise Value		



REPOTEC DATA DIGITIZATION

TAPE 2
4

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	AG 06	8 Aug 80	11.30	2	2	6	709

Target	Range	Bearing
BRG R04	5.2	131

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCNNAV — TAPSCN
R SNR — AVGSCN

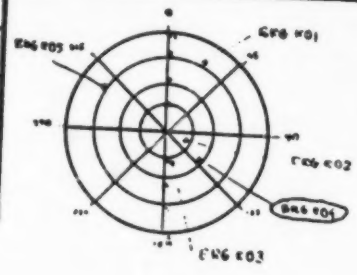
TAPE R35/R36

BRG R01	2.6	083
BRG R02	2.9	110
BRG R03	2.4	160
BRG R04	5.2	131
BRG R05	2.6	296

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74°.42' N
	Longitude	79° 21' W
	Heading	083
	Speed	1.2 kTs
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	2 kTs
	Wind Direction	263
	Precipitation	0
	Barometer	1018.6
	Cloud Cover	1/8
	Visibility	6 nM

RADAR	X1	S1
Cursor	125	
Sector Display	120 — 150	
# Scans Avg.	5	5
Signal Value	47	42
Noise Value	26	29



S Band
4.8 nM

REMOTEC DATA DIGITIZATION

TAPE 2
5

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	AG 06	8 Aug 80	11.30	2	2	6	709

Target	Range	Bearing
BRG R05	9.6	285

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	HP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

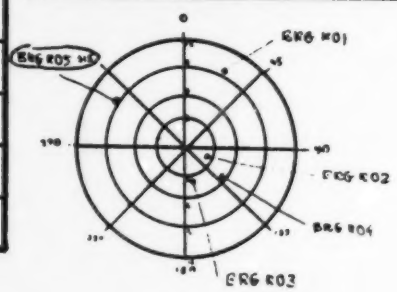
TAPE R35/R36

BRG R01	2.6	023
BRG R02	2.9	110
BRG R03	3.4	168
BRG R04	5.2	121
BRG R05	2.6	285

V. good for photos.

SHIP	Latitude	74°.42' N
	Longitude	79° 21' W
	Heading	093
	Speed	1.2 kTs
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	2 kTs
	Wind Direction	263
	Precipitation	0
	Barometer	1018.6
	Cloud Cover	1/8
	Visibility	6 nM

RADAR	X1	S1
Cursor	260	
Secor Display	250 – 290	
# Scans Avg.	5	3
Signal Value	52	53
Noise Value	26	26



TAPE 2
6

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	AD10	5 Aug 80	17.15	2	1	3	607

Target	Range	Bearing
BRG R06	6.28	230

PROGRAMS: File

R VERIFY — TAPSON
R JSCAN — TAPSON
R MSCAN — TAPSON
R SCANAV — TAPSON
R SNR — AVGSON

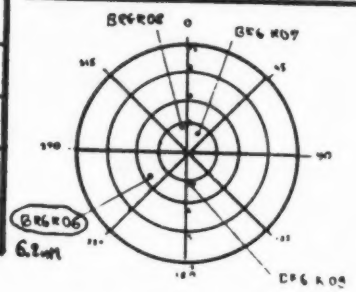
TAPE R10/R20
BRG R06 — 6.28 230
BRG R07 — 3.09 OLP
BRG R08 — 5.62 340
BRG R09 — 3.28 175
BRG R10 — 11.5 340
MORE TARGETS WORLD

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74°54' N
	Longitude	78°56' W
	Heading	031
	Speed	0.4 kTs
ENVIRONMENT	Sea State	0.3
	Temperature	—
	Wind Speed	8.0 kTS
	Wind Direction	140
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	3 nM

Good for plains / bubbles

RADAR	X2	S2
Cursor	220	
Secor Display	200 — 250	
# Scans Avg.	5	4
Signal Value	49	56
Noise Value	29	26



TAPE 2
7

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	RD10	5 Aug 80	17.15	2	1	3	607

Target	Range	Bearing
BRG R07	3.89	038

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCNAV — TAPSCN
R SNR — AVGSCN

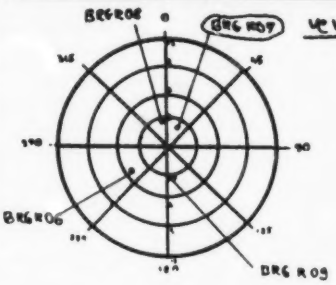
TRPW R10/R20
BRG R06 — 5.28 330
BRG R07 — 3.89 038
BRG R08 — 5.61 340
BRG R09 — 3.28 175

MORE TARGETS WORLD

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	24°54' N
	Longitude	78°56' W
	Heading	031
	Speed	0.4 kts
ENVIRONMENT	Sea State	0.3
	Temperature	—
	Wind Speed	8.0 kts
	Wind Direction	140
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	3 nM.

RADAR	X2	S2
Cursor	030	
Secor Display	010 — 060	
# Scans Avg.	5	3
Signal Value	36	52
Noise Value	28	38



VERY SMALL

TAPE 2
9

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	AD10	5 Aug 80	17.15	2	1	3	607

Target	Range	Bearing
BRG R09	8.5	175

PROGRAMS: File

R VERIFY — TAPSCN
R JSCNN — TAPSCN
R MSCNN — TAPSCN
R SCRNAV — TAPSCN
R SNR — AVGSCN

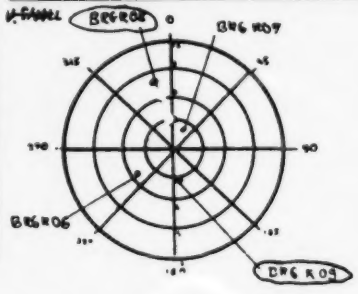
TAPE R10/R20
BRG R06 — 5.2 230
BRG R07 — 2.9 080
BRG R08 — 5.6 340
BRG R09 — 8.5 175
MORE TARGETS NEEDED

Ring	nM	km	
(1)	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

background + 2 fields

SHIP	Latitude	74°54' N
	Longitude	78°56' W
	Heading	031
	Speed	0.4 kts
ENVIRONMENT	Sea State	0.3
	Temperature	—
	Wind Speed	8.0 kts
	Wind Direction	140
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	3 nM

RADAR	X2	S2
Cursor	170	
Secor Display	160 — 190	
# Scans Avg.	5	5
Signal Value	45	51
Noise Value	38	26



TAPE 2
10

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
23 Aug 84	AD10	5 Aug 80	17.15	2	1	3	607

Target	Range	Bearing
BRG R10	11.5	240

PROGRAMS: File

R VERIFY — TAPSCN
R JSCNN — TAPSCN
R MSCNN — TAPSCN
R SCNNAV — TAPSCN
R SNR — AVGSCN

TAPE R10/R20

BRG R06 — 5.2P 230
BRG R07 — 2.0P 030
BRG R08 — 5.6P 340
BRG R09 — 3.2P 175

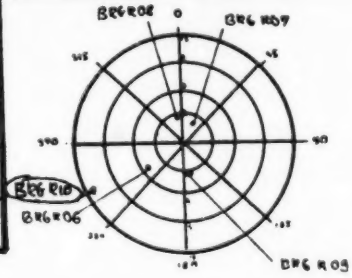
MORE TARGETS NEEDED

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

goal few plots

SHIP	Latitude	74°.54' N
	Longitude	78°.56' W
	Heading	031
	Speed	0.4 kTs
ENVIRONMENT	Sea State	0.3
	Temperature	—
	Wind Speed	8.0 kTS
	Wind Direction	140
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	3 nM

RADAR	X2	S2
Cursor	220	
Secor Display	200 — 250	
# Scans Avg.	5	4
Signal Value	59	47
Noise Value	29	26



TAPE 3
11 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
24 Aug 84	CO-03	70ct 80	15.45	2	1 1	3 4	810

Target	Range	Bearing
B RG R 10	7.0	070

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCNNAV — TAPSCN
R SNR — AVGSCN

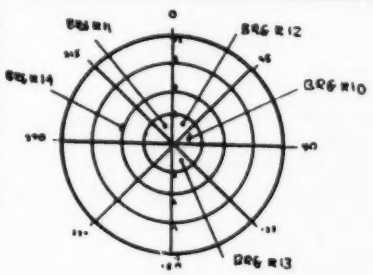
TAPE R250/R251
BRG R10 — 167 070
BRG R11 — 14 325
BRG R12 — 39 036
BRG R13 — 44 151
BRG R14 — 62 282
19 targets verified

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	70° 34'.01 N
	Longitude	67° 08'.98 W
	Heading	151
	Speed	8.8
ENVIRONMENT	Sea State	1
	Temperature	—
	Wind Speed	6
	Wind Direction	360
	Precipitation	0
	Barometer	1021.5
	Cloud Cover	8/8
	Visibility	> 27 nM

quad for plots

RADAR	X1	S1
Cursor	050	
Secor Display	040 — 080	
# Scans Avg.	5	5
Signal Value	63	49
Noise Value	18	23



REMOTEC DATA DIGITIZATION

TAPE 3
13 A

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
24 Aug 84	CO-03	7 Oct 80	15.45	2	1 1	3 4	810

Target	Range	Bearing
BRG R12	3.7	036

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

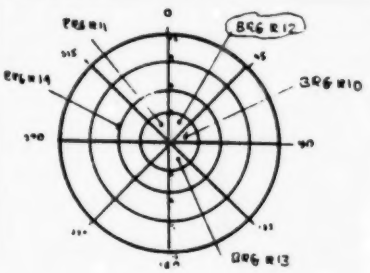
TAPE R250/R251		
BRG R10 — 1.6		070
BRG R11 — 3.4		325
BRG R12 — 3.7		036
BRG R13 — 4.4		151
BRG R14 — 6.2		288
18 targets visible		

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

good plots

SHIP	Latitude	70° 34'.01 N
	Longitude	67° 08'.78 W
	Heading	151
	Speed	8.8
ENVIRONMENT	Sea State	1
	Temperature	—
	Wind Speed	6
	Wind Direction	360
	Precipitation	0
	Barometer	1021.5
	Cloud Cover	8/8
	Visibility	> 27 nM

RADAR	X1	S1
Cursor	030	
Sector Display	020 — 050	
# Scans Avg.	5	5
Signal Value	NV	38
Noise Value		24



TAPE 3
14 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
24 Aug 84	CO-03	7 Oct 80	15.45	2	1 1	3 4	810

Target	Range	Bearing
BR6 R13	6.4	151

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCNAV — TAPSCN
R SNR — AVGSCN

TAPE R250/R251
BR6 R10 — 1.6 070
BR6 R11 — 3.4 325
BR6 R12 — 3.9 036
BR6 R13 — 6.4 151
BR6 R14 — 6.2 288
18 targets visible

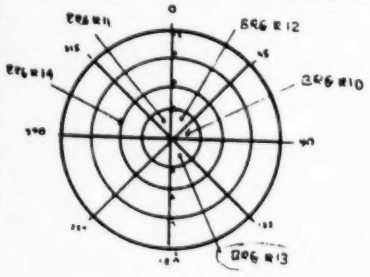
Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

gun fire pitch

SHIP		
	Latitude	70° 34'.01 N
	Longitude	67° 08'.78 W
	Heading	151
	Speed	8.8

ENVIRONMENT		
	Sea State	1
	Temperature	—
	Wind Speed	6
	Wind Direction	360
	Precipitation	0
	Barometer	1021.5
	Cloud Cover	8/8
	Visibility	> 27 nM

RADAR	X1	S1
Cursor	150	
Secor Display	135 — 165	
# Scans Avg.	5	5
Signal Value	64	50
Noise Value	19	24



TAPE 3
15 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
24 Aug 84	CO-03	7 Oct 80	15.45	2	1 1	3 4	810

Target	Range	Bearing
BRG R14	8.5	288°

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

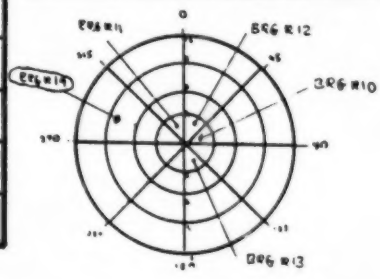
TAPE R250/R251

BRG R10 — 1.6 070
BRG R11 — 3.4 325
BRG R12 — 3.7 036
BRG R13 — 4.4 151
BRG R14 — 8.5 288
18 targets visible

Good fix points

S H I P	Latitude	70° 34'.01 N
	Longitude	67° 08'.98 W
	Heading	151
	Speed	8.8
E N V I R O N M E N T	Sea State	1
	Temperature	—
	Wind Speed	6
	Wind Direction	360
	Precipitation	0
	Barometer	1021.5
	Cloud Cover	8/8
	Visibility	> 27 nM

RADAR	X1	S1
Cursor	280	
Secor Display	260 — 300	
# Scans Avg.	5	4
Signal Value	63	46
Noise Value	18	23



TAPE 3
16 B

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
29 Aug 84	BH01	9 Sept 80	03.45	4S	16 16	3 4	035 048

Target	Range	Bearing
BR6 R15	7.2 nM	85

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R146/147

BR6 R15	X2	095	
BR6 R16	[illegible]	228	
BR6 R17	9.4	182	
BR6 R18	9.8	834	

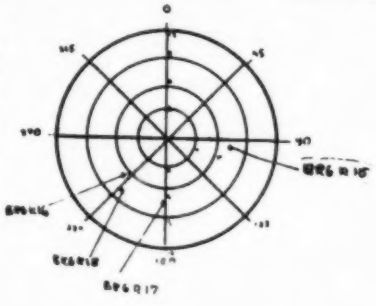
SMALL WAS V. SMALL THOUGH

Ring	nM	km	
①	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

grid Pos photo

S H I P	Latitude	74° 23.29' N
	Longitude	80° 22.45 W
	Heading	153.3
	Speed	8.9 kTs
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	8 kTs
	Wind Direction	025
	Precipitation	0
	Barometer	998.8
	Cloud Cover	8/8
	Visibility	2 nM

RADAR	X2	S2
Cursor	80	
Secor Display	90 — 90	
# Scans Avg.	5	5
Signal Value	63	60
Noise Value	23	25



TAPE 3
19 D

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
27 Aug 84	BH01	9 Sept 80	03.45	4S	16 16	3 4	035 048

Target	Range	Bearing
BRG R17	2.8	178

PROGRAMS: File

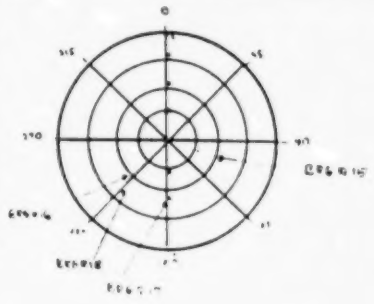
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R146/147
BRG R15 2.2 095
BRG R16 6.5 228
BRG R17 2.8 178
BRG R18 9.8 224
SMALL RNG V.S MALL TARGETS

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

S	Latitude	74° 22.29' N
H	Longitude	80° 22.43' W
I	Heading	153.3
P	Speed	8.9 kts
E	Sea State	0
N	Temperature	—
V	Wind Speed	8 kts
I	Wind Direction	025
R	Precipitation	0
O	Barometer	998.8
N	Cloud Cover	8/8
M	Visibility	2 nM
E		
N		
T		

RADAR	X2	S2
Cursor	200	
Secor Display	175 - 235	
# Scans Avg.	4	3
Signal Value	63	64
Noise Value	25	21



TAPE 3
18 B

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
27 Aug 84	BH01	9 Sept 80	02.45	4S	16 16	3 4	035 048

Target	Range	Bearing
BRG R18	7.8	224

PROGRAMS: File

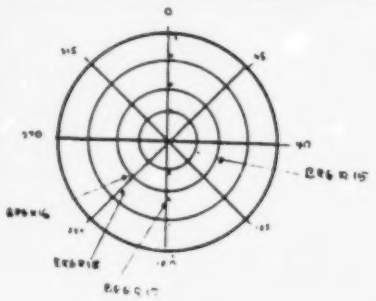
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R146/147
BRG R15 22 085
BRG R16 65 228
BRG R17 2.8 178
BRG R18 7.8 224
SMALL WAND W/SMALL TARGETS

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 22.25' N
	Longitude	80° 22.45 W
	Heading	153.3
	Speed	8.9 kts
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	8 kts
	Wind Direction	025
	Precipitation	0
	Barometer	998.8
	Cloud Cover	8/8
	Visibility	2 nM

RADAR	X2	S2
Cursor	200	
Sector Display	175 - 235	
# Scans Avg.	4	3
Signal Value	over 65	55
Noise Value	25	21



TAPE 4
20 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
26 Oct 84	AA 06	2 Aug 80	13.45	2	1	3	703

Target	Range	Bearing
BRG #21	5.8 nM	308

PROGRAMS: File

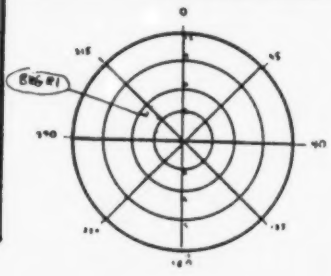
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE 107/RP

Ring	nM	km	
(1)	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74.04 N
	Longitude	62.10 W
	Heading	274
	Speed	9.1 KTS
ENVIRONMENT	Sea State	1
	Temperature	—
	Wind Speed	6 KTS
	Wind Direction	255
	Precipitation	Fog
	Barometer	1023
	Cloud Cover	Fog
	Visibility	1.5 nM

RADAR	X1	S1
Cursor	310	
Secor Display	290 — 330	
# Scans Avg.	4	3
Signal Value	40	44
Noise Value	34	25



REDTEC DATA DIGITIZATION

TAPE 4
21 A

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
26 Oct 81	AA06	2 Aug 80	13.45	2	1	3	703

Target	Range	Bearing
Brg R 22	4 nm	312

PROGRAMS: File

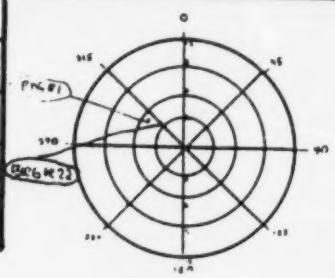
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R7/R8

Ring	nM	km	
(1)	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74.04 N
	Longitude	68.10 W
	Heading	274
	Speed	21 kts
ENVIRONMENT	Sea State	1
	Temperature	—
	Wind Speed	6 kts
	Wind Direction	255
	Precipitation	Fog
	Barometer	1023
	Cloud Cover	Fog
	Visibility	1.5 nm

RADAR	X1	S1
Cursor	310	
Secor Display	290 — 330	
# Scans Avg.	5	3
Signal Value	NV	45
Noise Value		25



TAPE 4
22A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
26 Oct 80	AA06	2 July 80	13.45	2	1	3	703

Target	Range	Bearing
BRG R23	2.4 nm	310

PROGRAMS: File

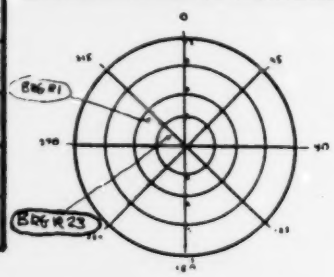
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R7/R8

Ring	nM	km	
(1)	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74.0 N
	Longitude	63.0 W
	Heading	274
	Speed	9.1 kts
ENVIRONMENT	Sea State	1
	Temperature	—
	Wind Speed	6 kts
	Wind Direction	255
	Precipitation	Fog
	Barometer	1023
	Cloud Cover	Fog
	Visibility	1.5 nm

RADAR	X1	S1
Cursor	310	
Secor Display	290 — 330	
# Scans Avg.	5	3
Signal Value	NV	56
Noise Value		25



TAPE 5
24 ⓪

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
310ct84	AB 11	3 Aug 80	21.15	2	2	4	740

Target	Range	Bearing
Brg 235	2.0 nM	168

PROGRAMS: File

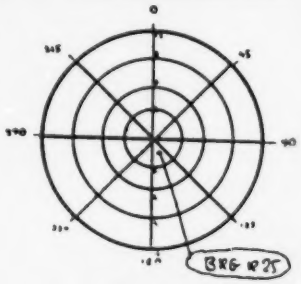
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R HSCAN — TAPSCN
R SCNNAV — TAPSCN
R SNR — AVGSCN

TAPE R11/R12
part of Lawn
VERY SMALL THREAT.

Ring	nM	km	
①	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 36' N
	Longitude	81° 19' W
	Heading	281
	Speed	0
ENVIRONMENT	Sea State	2
	Temperature	—
	Wind Speed	10 kts
	Wind Direction	050
	Precipitation	RAIN
	Barometer	1020
	Cloud Cover	8/8
	Visibility	5 nM

RADAR	X1	S1
Cursor	180	
Secor Display	160 — 190	
# Scans Avg.	5	5
Signal Value	32	33
Noise Value	19	21



TAPE 5
25 ④

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
310ct84	AB12	3 Aug 80	23.16	2	1	6	820

Target	Range	Bearing
Bog # 26	3.87 nM	180

PROGRAMS: File

R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

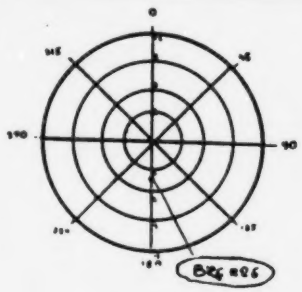
TAPE R11/R12

part of Lancet and one target

Ring	nM	km	
①	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

S	Latitude	74° 39' N
H	Longitude	80° 49' W
I	Heading	047
P	Speed	9.1 kts
E	Sea State	1
N	Temperature	—
V	Wind Speed	15 kts
I	Wind Direction	360
R	Precipitation	RAIN
O	Barometer	1018
N	Cloud Cover	overcast
M	Visibility	12 nM
E		
N		
T		

RADAR	X2	S2
Cursor	180	
Secor Display	160 — 200	
# Scans Avg.	4	4
Signal Value	NV	NV
Noise Value	—	—



TAPE 6
26

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
31 Oct 84	ADO8	5 Aug 80	13.15	2	1/2	3/1	351 ERG

Target	Range	Bearing
ERG R27	3.8	014

PROGRAMS: File

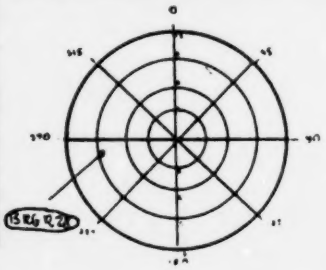
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCNAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R26
ERG R28 8.5nM 240

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	LP
3	27.0 - 40.5	50.0 - 75.0	LP
4	40.5 - 54.0	75.0 -100.0	LP
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	MP
3	7.0 - 10.5	13.0 - 19.5	MP
4	10.5 - 14.0	19.5 - 26.0	MP

SHIP	Latitude	74°59' N
	Longitude	78°03' W
	Heading	040
	Speed	0
ENVIRONMENT	Sea State	3
	Temperature	—
	Wind Speed	10 KTS
	Wind Direction	110/140
	Precipitation	0
	Barometer	1027.3
	Cloud Cover	8/8
	Visibility	1/8 NM

RADAR	X1	S1
Cursor	010 220	
Secor Display	000 200 —	040 260
# Scans Avg.	3	3
Signal Value	N.V. N.V.	N.V. N.V.
Noise Value	—	



TAPE 6
27 B

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
31 Oct 84	AD11	05 Aug 80	19.00	4S	17	1	707

Target	Range	Bearing
BRG R39	54	075

PROGRAMS: File

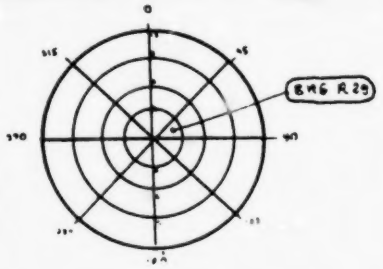
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R20

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 54' N
	Longitude	78° 48' W
	Heading	060
	Speed	0
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	6 kts
	Wind Direction	200
	Precipitation	0
	Barometer	1026
	Cloud Cover	8/8
	Visibility	5nM

RADAR	X2	S2
Cursor	070	
Secor Display	060 — 090	
# Scans Avg.	3	5
Signal Value	48	Model Lost Out in Fog
Noise Value	31	



TAPE 7 28 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
8 Nov 84	AD 12 (11?)	5 Aug 80	20.15	2	1	3	980

Target	Range	Bearing
BEG R31	1.5 nM	062

PROGRAMS: File

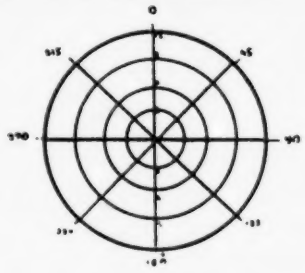
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R20

Ring	nM	km	
①	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 58' N
	Longitude	79° 15' W
	Heading	008
	Speed	0
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	5 KTs
	Wind Direction	164
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	4 nM

RADAR	X1	S1
Cursor	055	
Secor Display	040 — 080	
# Scans Avg.	4	4
Signal Value	55	56
Noise Value	18	21



TAPE 7 29 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
8 Nov 84	AD 18 (11?)	5 Aug 80	20.15	2	1	3	980

Target	Range	Bearing
BRG R 32	1.9 nM	058

PROGRAMS: File

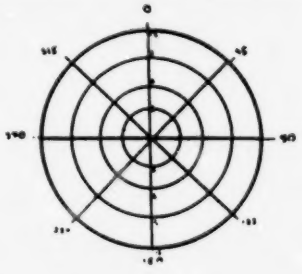
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R20

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 58' N
	Longitude	79° 15' W
	Heading	008
	Speed	0
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	5 KTs
	Wind Direction	164
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	4 nM

RADAR	X1	S1
Cursor	055	
Secor Display	040 — 080	
# Scans Avg.	4	4
Signal Value	55	56
Noise Value	18	21



TAPE 7 30 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
8 Nov 84	AD 12 (11?)	5 Aug 80	20.15	2	1	3	780

Target	Range	Bearing
BRG R 33	2.4 nM	070

PROGRAMS: File

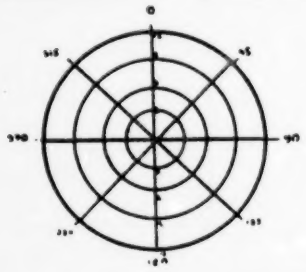
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCNAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R20

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	HP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 58' N
	Longitude	79° 15' W
	Heading	008
	Speed	0
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	5 KTs
	Wind Direction	164
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	4 nM

RADAR	X1	S1
Cursor	055	
Secor Display	040 — 080	
# Scans Avg.	4	4
Signal Value	55	55
Noise Value	18	21



TAPE 7 31 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
8 Nov 84	AD 12 (11?)	5 Aug 80	20.15	2	1	3	780

Target	Range	Bearing
BRG R34	4.0 nM	057

PROGRAMS: File

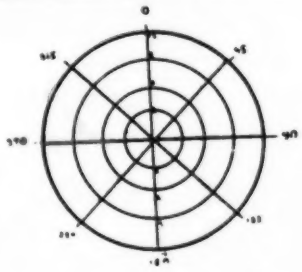
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R20

Ring	nM	km	
①	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 58' N
	Longitude	79° 15' W
	Heading	008
	Speed	0
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	5 kTs
	Wind Direction	164
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	4 nM

RADAR	X1	S1
Cursor	055	
Secor Display	040 — 080	
# Scans Avg.	4	4
Signal Value	54	55
Noise Value	18	21



TAPE 7 32 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
8 Nov 84	AD 18 (11?)	5 Aug 80	20.15	2	1	3	980

Target	Range	Bearing
BRG R35	4.3 nM	065

PROGRAMS: File

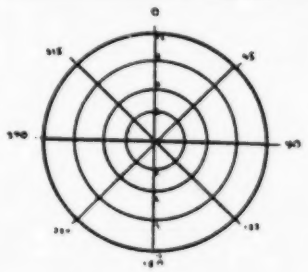
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R20

Ring	nM	km	
1	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	
3	27.0 - 40.5	50.0 - 75.0	
4	40.5 - 54.0	75.0 -100.0	
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	
3	7.0 - 10.5	13.0 - 19.5	
4	10.5 - 14.0	19.5 - 26.0	

SHIP	Latitude	74° 58' N
	Longitude	79° 15' W
	Heading	008
	Speed	0
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	5 KTs
	Wind Direction	164
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	4 nM

RADAR	X1	S1
Cursor	055	
Secor Display	040 — 080	
# Scans Avg.	4	4
Signal Value	52	56
Noise Value	18	21



TAPE 7 33 A

REMOTEC DATA DIGITIZATION

Date	Event No:	Event Date	Time	Mode	Sequence	Comb.	Counter
8 Nov 84	AD 18 (11?)	5 Aug 80	20.15	2	1	3	980

Target	Range	Bearing
BRG R36	5.2 nM	048

PROGRAMS: File

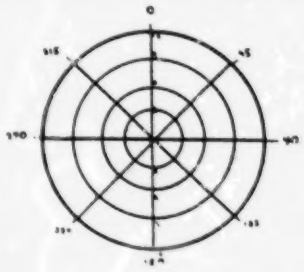
R VERIFY — TAPSCN
R JSCAN — TAPSCN
R MSCAN — TAPSCN
R SCANAV — TAPSCN
R SNR — AVGSCN

TAPE R19/R20

Ring	nM	km	
①	0.0 - 13.5	0.0 - 25.0	LP
2	13.5 - 27.0	25.0 - 50.0	LP
3	27.0 - 40.5	50.0 - 75.0	LP
4	40.5 - 54.0	75.0 -100.0	LP
1	0.0 - 3.5	0.0 - 6.5	MP
2	3.5 - 7.0	6.5 - 13.0	MP
3	7.0 - 10.5	13.0 - 19.5	MP
4	10.5 - 14.0	19.5 - 26.0	MP

SHIP	Latitude	74° 58' N
	Longitude	79° 15' W
	Heading	008
	Speed	0
ENVIRONMENT	Sea State	0
	Temperature	—
	Wind Speed	5 KTs
	Wind Direction	164
	Precipitation	0
	Barometer	1027
	Cloud Cover	8/8
	Visibility	4 nM

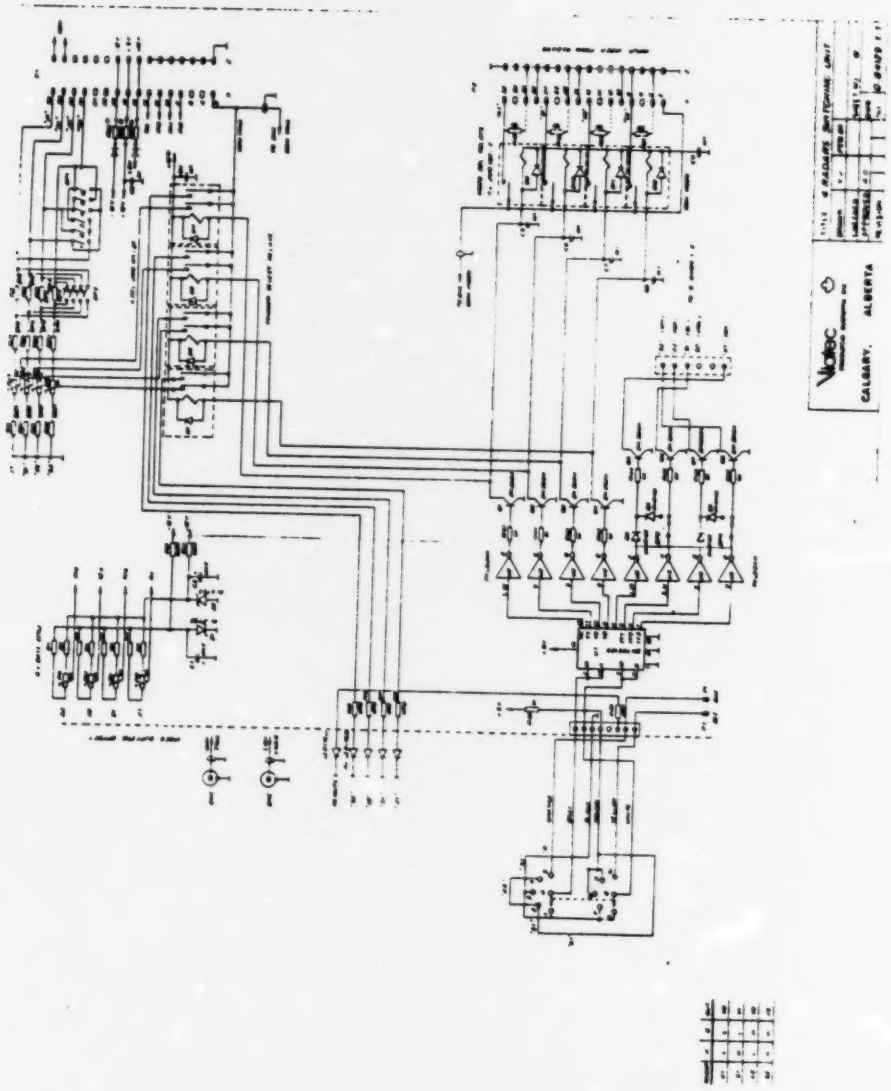
RADAR	X1	S1
Cursor	055	
Secor Display	040 — 020	
# Scans Avg.	4	4
Signal Value	48	54
Noise Value	18	21

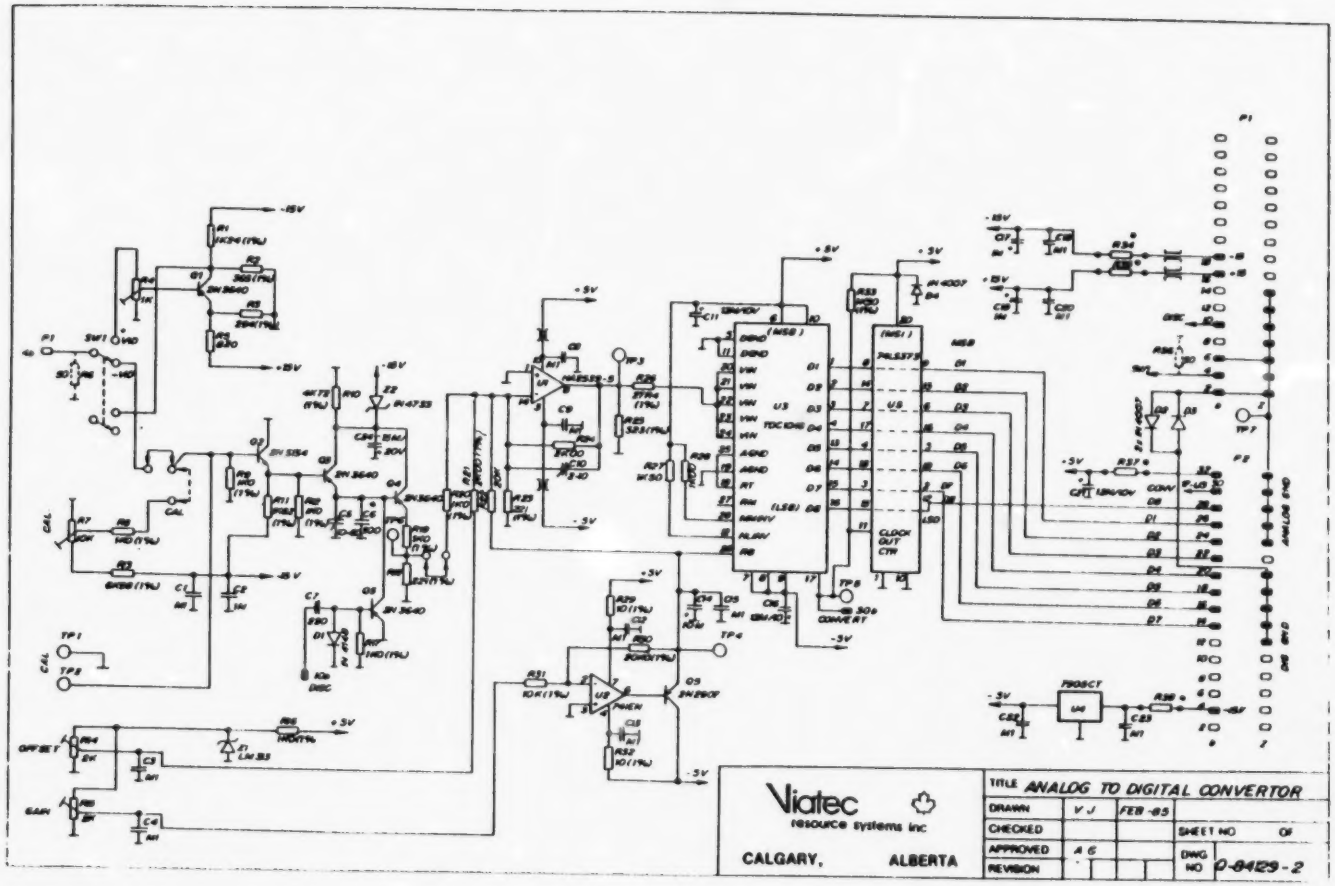


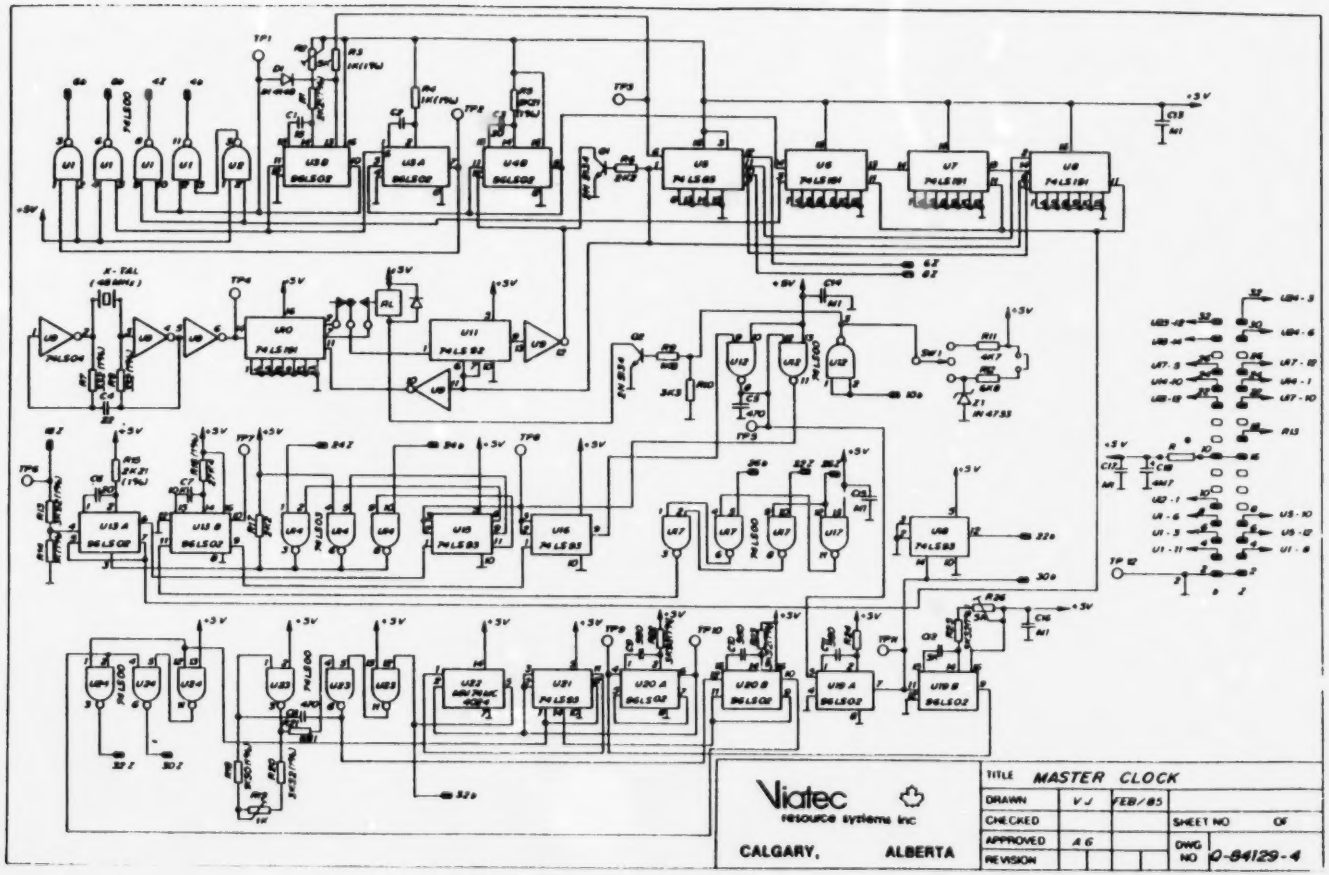
APPENDIX "B"

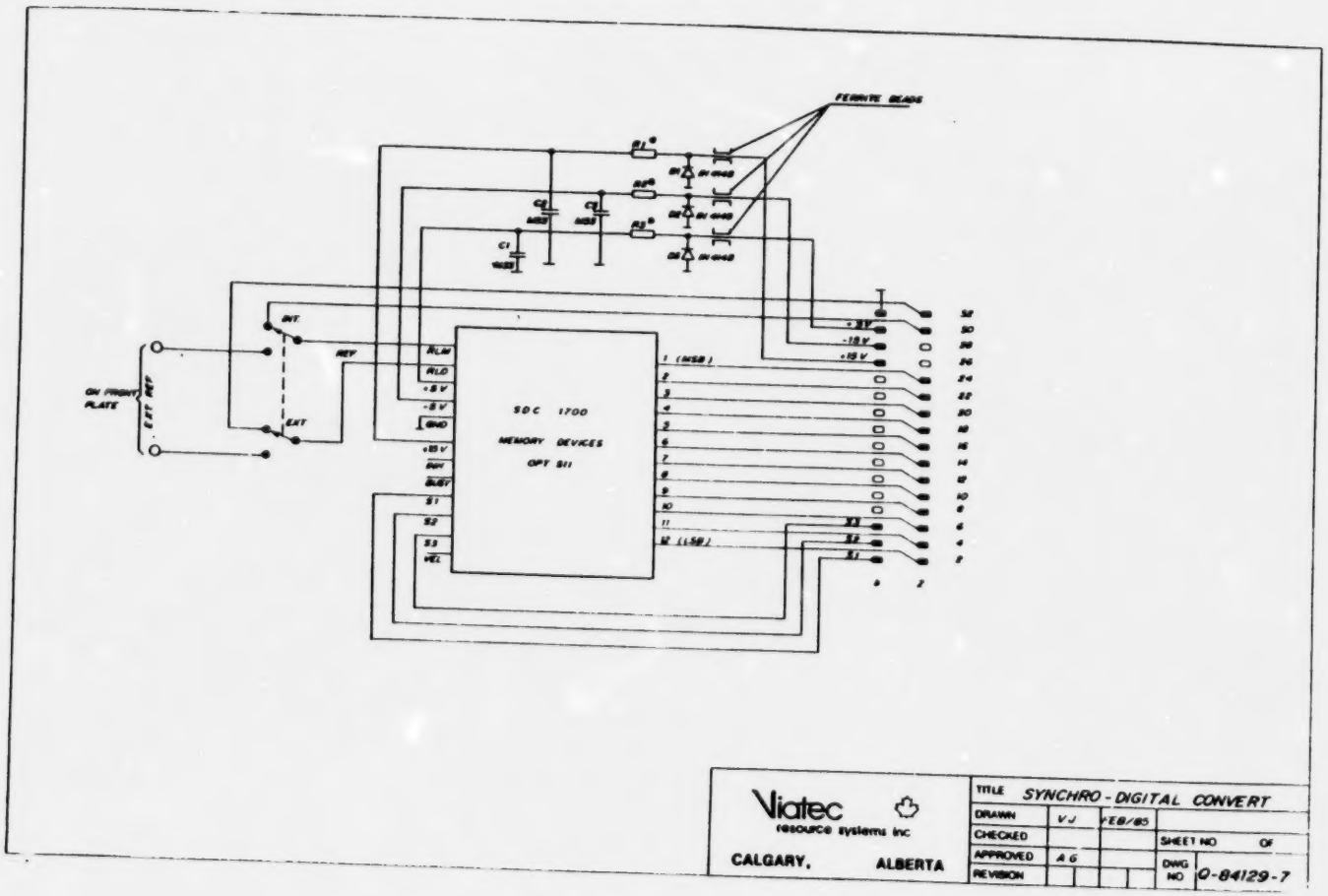
This contract was primarily involved with the investigation of different processing techniques utilizing, where possible, data collected by Remotec Applications Ltd. for Petro-Canada and the Transportation Development Center. One of those techniques first recommended by Viatec was the use of dynamic threshold processing described in Section 2. Instead of building a hardware version of this device, it was decided that it could be more effectively be implemented in a software version for more flexibility. This was accomplished, and in its place, a design for an upgraded analog to digital converter was produced. This is considered to be a more pressing problem as far as collecting and analyzing marine radar data was concerned.

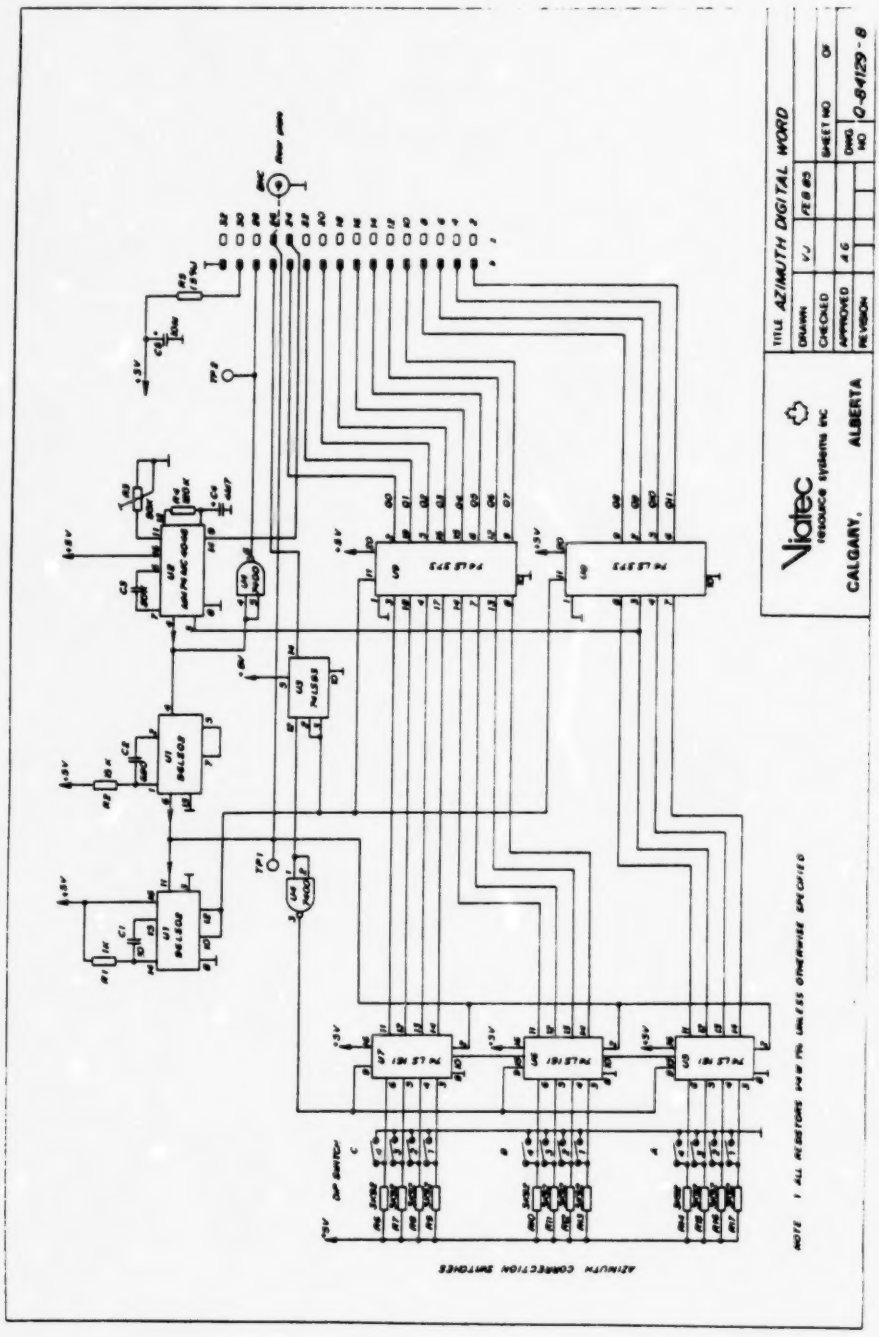
The following drawings illustrate the system as it currently exists. This system improves resolution from 6 bit to 8 bit. Future systems will require an improvement in sampling rate, from 6.5 MHz at present to ideally 18 MHz or more. This will be required in order to properly sample X band marine radar. In addition, real time scan conversion hardware will be required.

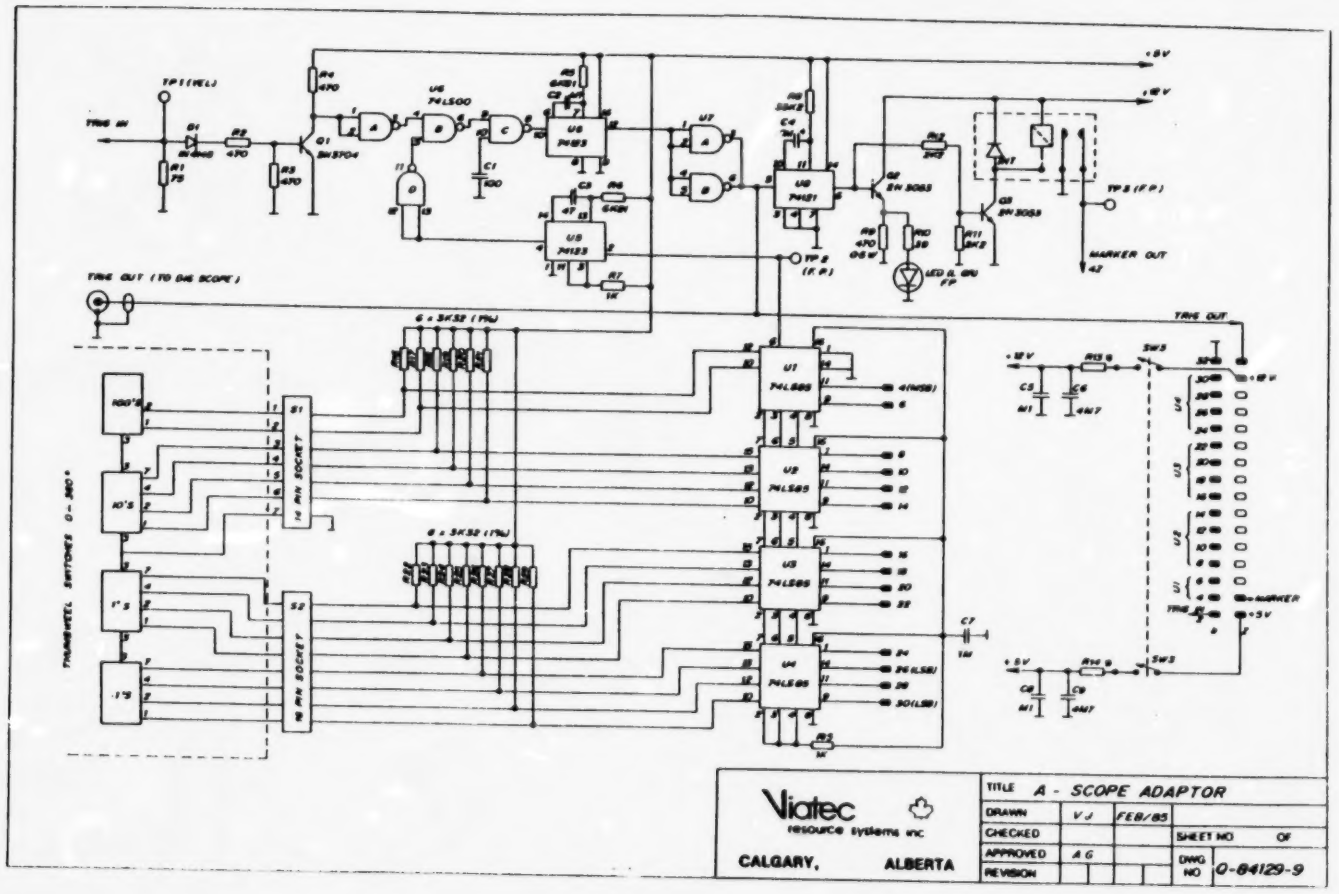


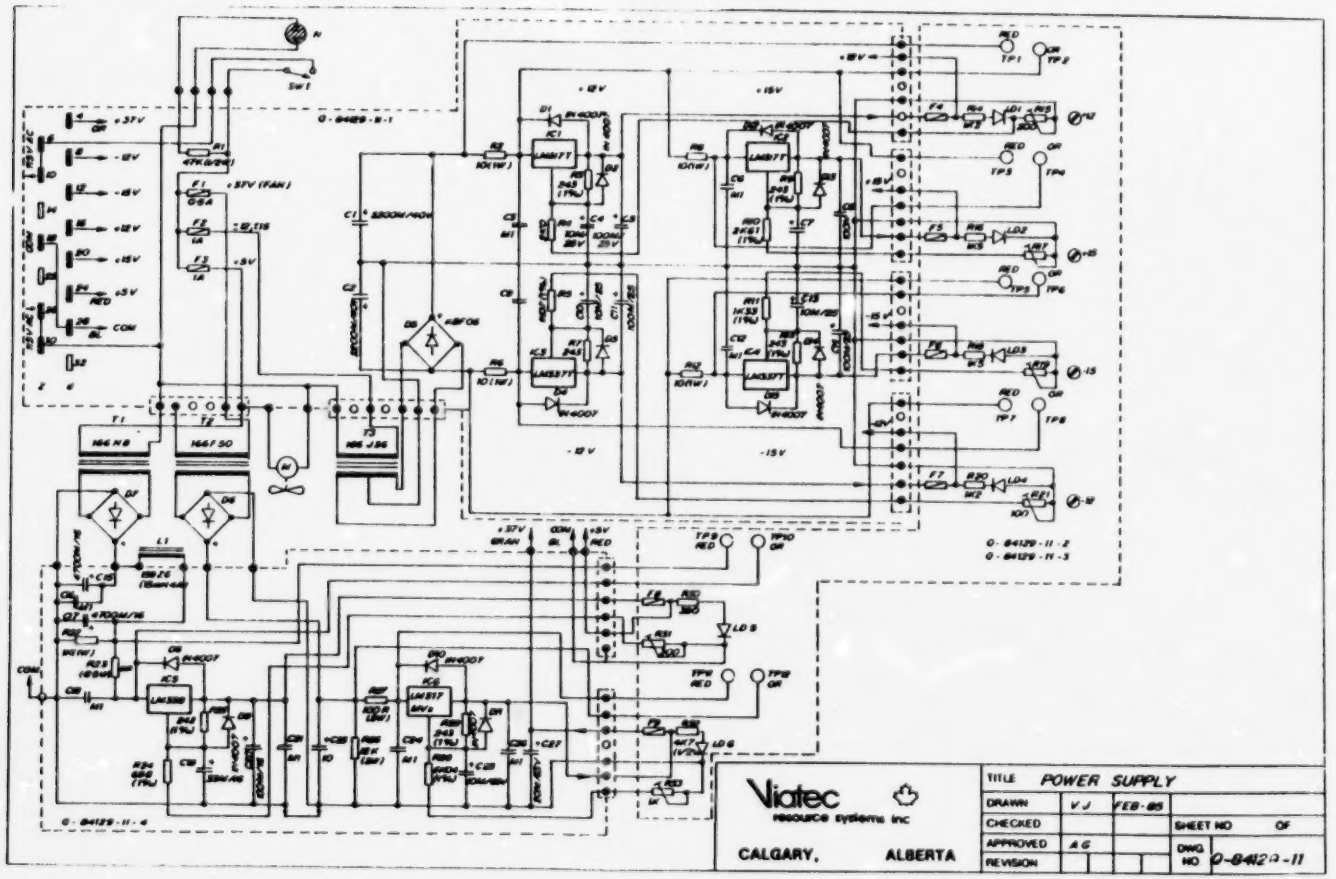

Viatec
resource systems inc
CALGARY, ALBERTA
TITLE ANALOG TO DIGITAL CONVERTOR
DRAWN VJ FEB-85
CHECKED
APPROVED AG
REVISION
SHEET NO OF
DWG NO D-8429-2

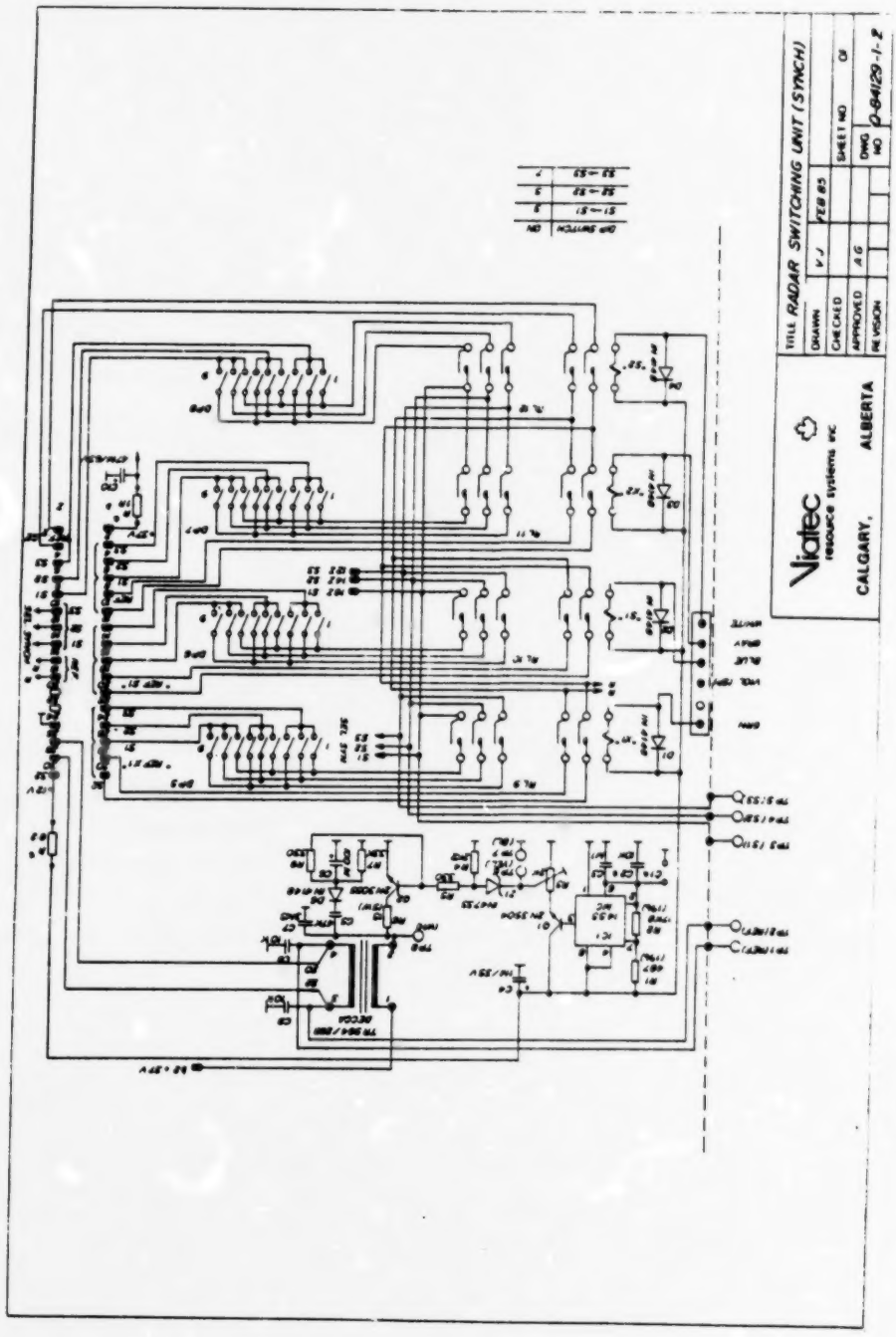

Viatec
resource systems inc
CALGARY, ALBERTA
TITLE MASTER CLOCK
DRAWN VJ FEB/85
CHECKED
APPROVED AG
REVISION
SHEET NO OF
DWG NO 0-84129-4

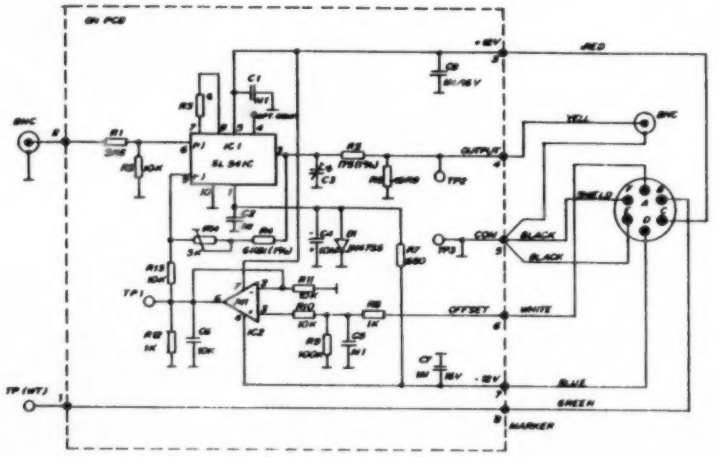

FERRITE BEADS
INT.
REF
EXT
ON FRONT PLATE
EXT REF
SDC 1700
MEMORY DEVICES
OPT 511
1 (MSB)
12 (LSB)
+5V
-15V
+15V
Viatec
resource systems inc
CALGARY, ALBERTA
TITLE SYNCHRO-DIGITAL CONVERT
DRAWN VJ FEB/85
CHECKED
APPROVED AG
REVISION
SHEET NO OF
DWG NO 0-84129-7


TITLE AZIMUTH DIGITAL WORD
DRAWN VJ FEB 85
CHECKED
APPROVED AG
REVISION
SHEET NO OF
DWG NO 0-84129-8
Viatec
resource systems inc
CALGARY, ALBERTA
AZIMUTH CORRECTION SWITCHES
NOTE 1 ALL RESISTORS 1/4W 5% UNLESS OTHERWISE SPECIFIED

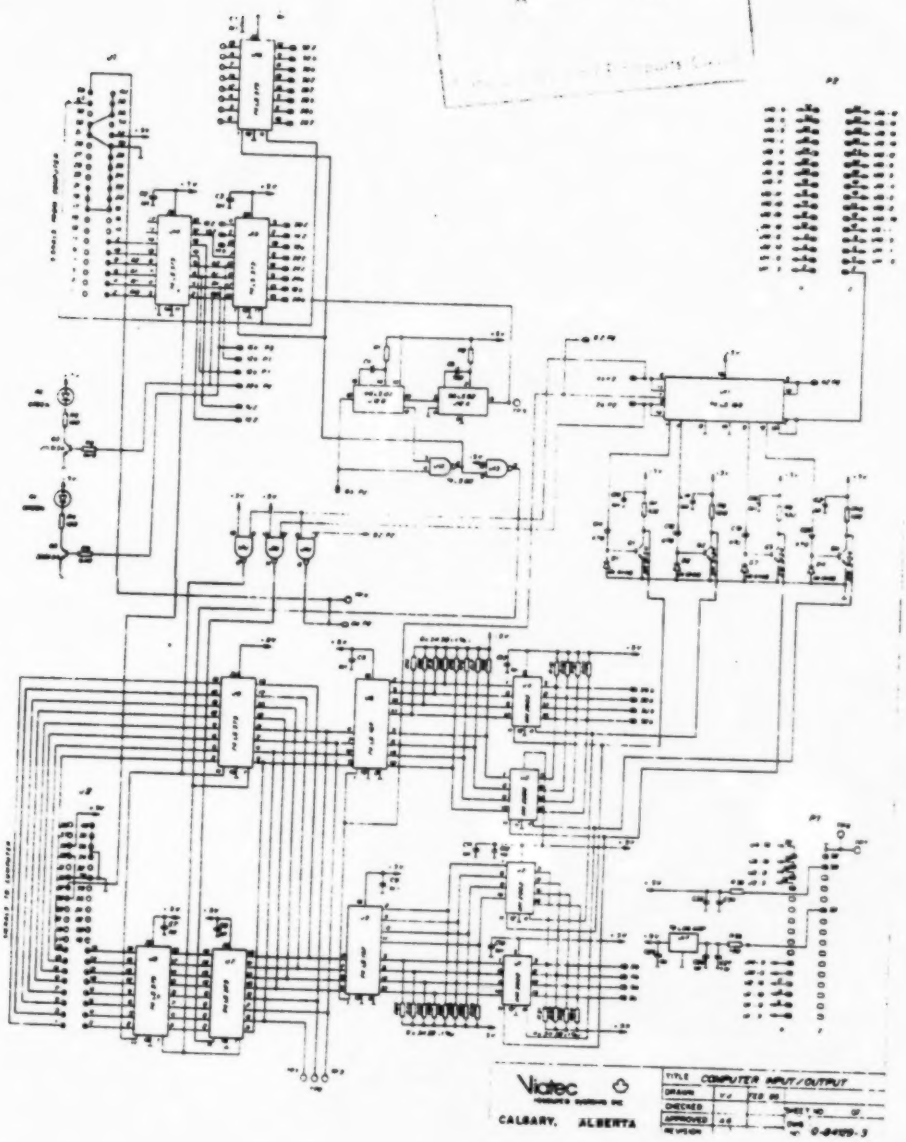

TRIG IN
TRIG OUT (TO DIG SCOPE)
TRIG OUT
MARKER OUT
TP1 (REL)
TP2 (F.P.)
TP3 (F.P.)
+5V
+12V
-12V
THUMBWHEEL SWITCHES 0 - 360°
100'S
10'S
1'S
.1'S
S1
S2
14 PIN SOCKET
16 PIN SOCKET
6 x 3K32 (TNJ)
8 x 3K32 (TNJ)
U1 74LS85
U2 74LS85
U3 74LS85
U4 74LS85
U5 74123
U6 74LS00
U7
U8 74121
Q1 2N3704
Q2 2N3053
Q3 2N3053
SW1
SW2
SW3
C1 100
C2 .047
C3 .047
C4 .1
C5 .1
C6 4M7
C7 1M
C8 .1
C9 4M7
R1 75
R2 470
R3 470
R4 470
R5 680Ω
R6 680Ω
R7 1K
R8 2K2
R9 470 0.5W
R10 330
R11 4K2
R12 2K2
R13 0
R14 0
R15 1K
LED (L 6N) FP
Viatec
resource systems inc.
CALGARY, ALBERTA
TITLE A - SCOPE ADAPTOR
DRAWN VJ FEB/85
CHECKED
APPROVED AG
REVISION
SHEET NO OF
DWG NO 0-84129-9


Viatec
resource systems inc
CALGARY, ALBERTA
TITLE POWER SUPPLY
DRAWN VJ FEB-85
CHECKED
APPROVED AG
REVISION
SHEET NO OF
DWG NO 0-8412A-11


TITLE RADAR SWITCHING UNIT (SYNCH)
DRAWN
CHECKED
APPROVED
REVISION
FEB 85
SHEET NO
OF
DWG NO
Viatec
resource systems inc
CALGARY, ALBERTA



Viatec resource systems inc	TITLE	VIDEO BUFFER		
CALGARY, ALBERTA	DRAWN	V J	FEB 85	
	CHECKED			SHEET NO OF
	APPROVED	A G		DWG NO 0-84128-0
	REVISION			


Viatec
CALGARY, ALBERTA
TITLE COMPUTER INPUT/OUTPUT
DRAWN
CHECKED
APPROVED